CARNEGIE INSTITUTION

OF

WASHINGTON

YEAR BOOK No. 16

1917

PUBLISHED BY THE INSTITUTION
WASHINGTON, U. S. A.
FEBRUARY 1918

12870

WASHINGTON, D. C.
PRESS OF GIBSON BROTHERS

OFFICERS FOR THE YEAR 1918.

LIST OF PRESENT AND FORMER TRUSTEES.

*Deceased.

ASSOCIATES OF THE INSTITUTION.

HEADS OF DEPARTMENTS OF RESEARCH.

Louis A. Bauer, *Director*, Department of Terrestrial Magnetism.
Francis G. Benedict, *Director*, Nutrition Laboratory.
Benjamin Boss, *Director*, Department of Meridian Astrometry.
Charles B. Davenport, *Director*, Department of Experimental Evolution.
Arthur L. Day, *Director*, Geophysical Laboratory.
George E. Hale, *Director*, Mount Wilson Solar Observatory.
J. Franklin Jameson, *Director*, Department of Historical Research.
Daniel T. MacDougal, *Director*, Department of Botanical Research.
*Franklin P. Mall, *Director*, Department of Embryology.
Alfred G. Mayer, *Director*, Department of Marine Biology.

OTHER INVESTIGATORS PRIMARILY CONNECTED WITH THE INSTITUTION.

William Churchill, Associate in Primitive Philology.
Frederic E. Clements, Associate in Ecology.
Oliver P. Hay, Associate in Paleontology.
Elias A. Loew, Associate in Paleography.
Sylvanus G. Morley, Associate in American Archeology.
Esther B. Van Deman, Associate in Roman Archeology.
George R. Wieland, Associate in Paleontology.

INVESTIGATORS PRIMARILY CONNECTED WITH OTHER ORGANIZATIONS.

Carl Barus (Brown University), Research Associate in Physics.
Henry Bergen, Research Associate in Literature.
V. Bjerknes (University at Bergen, Norway), Research Associate in Meteorology.
E. C. Case (University of Michigan), Research Associate in Paleontology.
W. E. Castle (Harvard University), Research Associate in Biology.
T. C. Chamberlin (University of Chicago), Research Associate in Geology.
J. C. W. Frazer (Johns Hopkins University), Research Associate in Chemistry.
John F. Hayford (Northwestern University), Research Associate in Physics.
Henry M. Howe (Columbia University), Research Associate in Metallurgy.
L. B. Mendel (Yale University), Research Associate in Physiological Chemistry.
T. H. Morgan (Columbia University), Research Associate in Biology.
Frank Morley (Johns Hopkins University), Research Associate in Mathematics.
H. N. Morse (Johns Hopkins University), Research Associate in Chemistry.
F. R. Moulton (University of Chicago), Research Associate in Mathematical Physics.
E. L. Nichols (Cornell University), Research Associate in Physics.
A. A. Noyes (Massachusetts Institute of Technology), Research Associate in Chemistry.
Thomas B. Osborne (Connecticut Agricultural Experiment Station), Research Associate in Physiological Chemistry.
H. L. Osgood (Columbia University), Research Associate in History.
T. W. Richards (Harvard University), Research Associate in Chemistry.
H. C. Sherman (Columbia University), Research Associate in Chemistry.
Edgar F. Smith (University of Pennsylvania), Research Associate in Chemistry.
John S. P. Tatlock (Leland Stanford Junior University), Research Associate in Literature.

*Died November 17, 1917.

CONTENTS.

ORGANIZATION, PLAN AND SCOPE.

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the Trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and to printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION.

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be in enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corpora-

tion hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

Sec. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

Sec. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

Sec. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

Article I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

Article II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

Article III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

SIXTEENTH MEETING OF THE BOARD OF TRUSTEES

ABSTRACT OF MINUTES OF THE SIXTEENTH MEETING OF BOARD OF TRUSTEES.

The meeting was held in Washington, in the Board Room of the Administration Building, on Friday, December 14, 1917, and was called to order at 10 a. m. by the chairman, Mr. Root.

In the absence of the secretary, Mr. C. D. Walcott was elected temporary secretary. Upon roll-call, the following Trustees responded: Robert S. Brookings, John J. Carty, Charles P. Fenner, Myron T. Herrick, Henry L. Higginson, Charles L. Hutchinson, Henry Cabot Lodge, Andrew J. Montague, William W. Morrow, Stewart Paton, Henry S. Pritchett, Elihu Root, Theobald Smith, Charles D. Walcott, Henry P. Walcott, Henry White, George W. Wickersham, Robert S. Woodward.

The minutes of the fifteenth meeting were approved as printed and submitted to members of the Board of Trustees.

The reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of directors of departments and grantees of the Institution were presented and considered.

The following appropriations for the year 1918 were authorized:

Administration	$ 53,000.00
Publication	60,000.00
Division of Publications	12,000.00
Departments of Research	672,180.00
Minor grants	88,440.00
Index Medicus	12,000.00
Insurance fund	25,000.00
Reserve fund	250,000.00
	1,172,620.00

Balloting to fill a vacancy in the Board of Trustees, caused by the resignation of Mr. Andrew D. White, resulted in the election of Mr. James Parmelee, of Washington, D. C., to membership in the Board.

Messrs. Henry White and C. D. Walcott were reelected as members of the Executive Committee for a term of three years.

The proposal of Mrs. E. H. Harriman to donate to the Carnegie Institution of Washington the Eugenics Record Office, together

with eighty acres of land at Cold Spring Harbor, the buildings erected thereon, and securities yielding an income of $12,000 per annum, was formally accepted by the Trustees, and authorization was given to proceed with the work of said office.

The following resolutions were passed:

Resolved, That there be established a fund to be called the Pension Fund, to meet accrued and accruing liabilities of the Institution under the insurance and annuities plan for members of the Institution as contemplated in the resolution passed by the Executive Committee at its meeting of November 19, 1917.

Resolved, That the sum of $40,000 be and hereby is appropriated from the unappropriated balance available for the year 1917 to the Pension Fund of the Institution and that the budget for 1918 be amended accordingly.

The meeting adjourned at $12^h 15^m$ p. m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1917.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1917, along with recommendations of appropriations for the ensuing year and with sundry suggestions concerning other matters of general or special interest.

This report is the sixteenth annual administrative report of the Institution and is presented under the following principal heads:

1. Some noteworthy events of the year.
2. The Institution and the public.
3. Researches of the year.
4. Financial records.
5. Publications of the year.
6. Proposals for budget for 1918.
7. Bibliographical appendix.

SOME NOTEWORTHY EVENTS OF THE YEAR.

To the great majority, apparently, of our contemporaries nothing could be easier than the successful launching of an altruistic enterprise like that undertaken by the Trustees of the Carnegie Institution of Washington when they accepted the Founder's remarkably favorable deed of trust in January 1902. The Trustees were given the largest liberties and what appeared at the time to be the amplest, if not unlimited, capital was placed at their disposal. Herein surely were conditions affording unparalleled opportunities, and it seemed essential only to sow the income broadcast in order to reap a rich harvest of results in the advancement of learning. That a careful, or even any, preparation of the ground was needed or that deliberate attention should be given to preliminary plans and specifications were considerations almost wholly ignored in

the popular mind. What obstacles could arise that would not be speedily swept aside by the resistless tide of the Institution's income, reinforced as then generally assumed, and still often assumed, by its endowment?

In Memoriam.

It is a fortunate circumstance, not only for the Institution but for all similar organizations as well, that this exuberant optimism was not wholly shared by those more immediately responsible for the stability and the permanence of the new enterprise. Among the Trustees who entertained a more rational optimism and thus rendered invaluable aid to the Institution during the critical period in question was Isaac Wayne MacVeagh, who served the organization from the date of its foundation in 1902 to 1907 and who died at his home in Washington, January 11, 1917.

Mr. MacVeagh was a native of Pennsylvania, having been born at Phoenixville, Chester County, April 19, 1833, and he was identified with that State during the greater part of his life. He is too well known as a distinguished American who devoted his time and talents in large degree to the public service to need extended mention here. It may suffice to remark that he brought into the councils of the Board of Trustees of the Institution the same fearless independence and the same high sense of justice and propriety which characterized him in public life. Although he did not take a notably active part in the proceedings of this Board or in those of the Executive Committee, he was keenly alive to the essentials of these proceedings and especially competent and ready to give advice concerning their legal and moral aspects. He served the Institution best by means of counsel given in the privacy of his home, where he spoke freely of men and measures and of the dangers which the Institution must encounter. He possessed extraordinary knowledge of men and affairs and corrresponding capacity to give enlightening advice concerning both. His versatility and his varied experience, supplemented by a reflective temperament, made him a national authority in legal, judicial, and diplomatic questions. He was a resolute advocate and antagonist in all such matters. But throughout his career there is dominant an elevated type of idealism never obscured either by public clamor or by personal triumphs in forensic fields. He accepted the fray of the work-

a-day world and played his part with uncommon vigor and discernment, but always also with a disposition of uncommon fairness, justice, and mercy. It was this disposition that made him a sympathetic and valued adviser of the Institution during the later years of his life, even after retiring from his trusteeship at the end of 1906.

Star Catalogue of Ulugh Beg.

During a period when one half of the world is at war with the other half, when governments long established are imperiled by the impulses of primitive men, leading in the extremes either to the excesses of autocracy or to the excesses of anarchy, there would seem to be little room for the consideration of the current events of a research establishment. Attention must be concentrated on the needs of states, whose stability and continuity are prerequisite to the existence of organizations devoted to abstract investigation. There appears to be scant opportunity for contemplative studies; time seems available only for the utilization of existing knowledge; the daily events of international conflict quite overshadow all others in immediate interest. But while public attention is properly engrossed in the exigencies of national and international affairs, it is well to recall that periods like the present have not been less fruitful in discoveries and advances of permanent value to our race than the periods of more peaceful activities. The course of human evolution has not run smoothly, and it does not appear to be destined to become frictionless in the near future. Neither has the general trend upward of mankind been unaccompanied by depressing reversions to the instincts of barbarism. But these sinister facts, so painfully verified in contemporary history, are mitigated by other facts which show that the essentials of progress will be the last to disappear in any possible reversion and that they may even survive and flourish amid the ruins of empires. Thus, while the ideas of Alexander and Cæsar and the long line of Greek and Roman statesmen, philosophers, and poets are still properly held to be highly worthy of critical study, it is plain that they are of a far less permanent character than the ideas, for example, of the Alexandrian school of scientists, whose contributions to knowledge relate to principles coextensive with the universe at large as well as with that small part of it wherein we happen temporarily to reside.

Similarly, it is now equally plain that the ideas of the chemist Berthollet and the mathematician Fourier who, about a century ago, stood with Napoleon before the pyramids while the centuries looked down upon them, have proved incomparably more worthy of preservation and development than the ideas of that autocrat. He and his statecraft perished, but the savants of his day, conspicuously typified by Lagrange, Laplace, and Lavoisier, have won increasing and world-wide regard with the lapse of time.

It appears not inappropriate, therefore, in line with these reflections, to cite here among the noteworthy events of the year in the history of the Institution the publication of a new (and probably final) edition of the Catalogue of Stars of Ulugh Beg, an astronomer of the fifteenth century who "was the most famous as he was the last conspicuous representative of Arabian astronomy." He was the grandson of Tamerlane, but quite unlike this warrior ancestor he enjoys the distinction of having established an observatory near Samarkand (about A. D. 1420) and having founded his catalogue of stellar positions on original observations. The first edition, or manuscript account, of his work appeared about 1437, under the title Zij Ulugh Beg. It consists of an introductory section in four parts or chapters, followed by some thirty tables essential to astronomical calculations and by the catalogue of stellar positions. The table of contents of the work, republished in translation in the new edition, is profoundly instructive in the light it throws on the evolution of astronomical theory and astronomical practice; while peculiar humanistic interest should be aroused by the title of the fourth chapter, "Horoscopes and Nativities," since this indicates among other things that the distinguished author did not appreciate as keenly as do his successors the necessity of corrections for personal equation and for anthropocentric parallax.

This work stands in sequence with, and is the next most important work after, the Almagest of Ptolemy, an edition of which was published by the Institution a year ago; and it is a fortunate circumstance that the new edition of Ulugh Beg, like the edition of the Almagest just referred to, has been issued under the editorship of Mr. Edward Ball Knobel, Treasurer and past President of the Royal Astronomical Society of London. Mr. Knobel began investigation of the manuscripts of Ulugh Beg in 1879. His collaborator and co-author in the case of the Almagest, Dr.

C. H. F. Peters, gave much attention also in the later years of his life to the work of Ulugh Beg. His notes and comments have been utilized by Knobel, and a valuable vocabulary of Persian words prepared by Peters and revised by Knobel is published as an appendix to the work. These new editions of the Almagest and Zij Ulugh Beg show at a glance, to one acquainted with the subject, not only the relations between the attainments of the Greek school of astronomers and the corresponding attainments of the Arabian school, but in an equally summary and conclusive fashion they show the transcendent superiority of their modern successors over both schools. But while it appears that the Arabians did not make any noteworthy advances either in the theories or in the applications of astronomy, it must be admitted to their great credit that they were the chief conservators of the science between the epoch of Hipparchus and the epoch of Galileo.

A Concordance to the Poems of Keats.

Two other publications of the Institution issued during the year are worthy of special mention here, partly because they serve to indicate the activities of the Institution in widely different fields and partly because they serve, each in its own way, to meet the needs of specialists. They furnish also extreme instances of what may be called humanistic learning and help to disclose the pitfalls which beset one who may attempt, by a priori reasoning, to divide knowledge into technical and non-technical categories, concerning which some observations are made in a later section of this report.

The first of the works referred to is a concordance to the poems of John Keats, compiled by a zealous company of six editors assisted by no less than twenty-four collaborators. It not infrequently happens that two authors conspire to produce a book, but it is rare that thirty join in such a task. The work is a technical volume of about 450 quarto pages preceded by a carefully prepared introductory chapter drawn up by the leader of these editorial specialists, Professor Leslie Nathan Broughton. It will help to meet the needs of the rapidly growing number of critical scholars whose learning is required to be minutely special in order than it may be broadly liberal. Such works in literature, like numerical tables and catalogues of stellar positions in astronomy, furnish the data for advances and discoveries of ever increasing definiteness and permanence.

The second work referred to is the third volume of the researches of the Department of Terrestrial Magnetism. This work and the two previously published volumes in the same series bring down to near the end of the year 1916 the results of the magnetic survey of the earth carried on by this department during the past decade. They are thus available for immediate use as aids to navigation at a time when few data are accessible from other sources. It should be explained that such promptness in the publication of the results of investigations having direct applications is not customary. Their appearance, especially under governmental auspices, is often delayed for decades and in some cases until they are obsolete. Indeed, some branches of science are now overloaded with data so antiquated, so incomplete, or so untrustworthy that progress may be more rapidly attained by scrapping them and by the adoption of improved methods of procedure in the attainment of new data. It should be explained also that the Department of Terrestrial Magnetism has sought from the outset to avoid the futilities due to delays in publication as well as the dangers that arise from random and unrelated observations. In fact, preliminary results, accurate enough for incorporation in sailing charts, from the ocean surveys of the non-magnetic ship have been forwarded promptly to the principal chart-making offices of the world at the end of each cruise or whenever this vessel has made an important port.

Results of Magnetic Survey of the Earth.

The value of these results to navigation is almost as evident as the value of navigation itself. They not only facilitate directly the trade and the commerce of the world, but they contribute in a more important degree to the security and the enlightenment of humanity. Researches in such fields of endeavor must therefore be admitted to be humane if they may not be classed, like the Concordance to Keats, among those apparently more highly technical subjects of research called the humanities. It should be understood, however, that furnishing aids to navigation is not the only nor the most important reason for the existence of the Department of Terrestrial Magnetism. It is a favorable condition, of course, exemplified in the case of this department to a greater degree than in the case of any other, that the work in question meets with a ready popular appreciation and com-

mendation; but its existence must ultimately depend on the contributions it makes toward a solution of the problem of cosmic magnetism in which the earth, by reason of our residence thereon, would seem to play a dominant if not determining role.

Transfer of the Classics of International Law.

At their meeting in December 1908, the Board of Trustees of the Institution approved a plan for publication of the more important classics of international law. This project was proposed by Professor James Brown Scott in December 1907, and the plan as worked out by him in collaboration with the Division of Publications of the Institution contemplated reproduction of the classics in question by photographic methods from the best extant original or early editions and supplying for each volume of them a corresponding volume in English translation, thus giving the reader, or the investigator, the benefit simultaneously of the original texts (which are mostly in Latin) and authoritative English versions.

In accordance with this plan Professor Scott, who was at that time Solicitor of the Department of State, assumed the duties of supervising editor of the series. When the Carnegie Endowment for International Peace was established, in December 1910, Professor Scott became its Secretary and he has since served the Endowment in that capacity. In the meantime, as the issue and distribution of these classics proceeded, it became more and more evident that they fall appropriately and advantageously rather in the province of the Peace Endowment than in the province of the Institution. This fact was recognized by both organizations, and by mutual approval the Board of Trustees of the Institution, at their meeting of December 1916, authorized the transfer of the entire project, including the published volumes of the series on hand, to the Carnegie Endowment for International Peace. By the terms of the transfer the Endowment paid the Institution the pro rata costs of the volumes on hand and assumed liability for the costs of the volumes in press. The transfer has been completed during the year. The number of volumes issued under the auspices of the Institution and thus transferred is 14, with a total of 5,396 pages. They include, in the order of issue, the works of Zouche, Ayala, Vattel, Rachel, Textor, Victoria, and Legnano. A photographic reproduction of the work of Grotius, "De Jure Belli ac Pacis," has also been made but not issued.

Discontinuance of the Department of Economics and Sociology.

Among the many departments of research established by the Institution the one devoted to economics and sociology is exceptional. All the other departments have been conducted by directors and staffs primarily connected with and under salaries from the Institution; the Department of Economics and Sociology, on the other hand, was conducted by a board of distinguished collaborators primarily connected in most instances with other establishments and serving the Institution in most instances without compensation. This Board was under the chairmanship of a Trustee of the Institution, Dr. Carroll D. Wright, from the date of authorization in January 1904 until his death in January 1909. Thereafter the duties of this office were assumed by Professor Henry W. Farnam, who had previously served as secretary of the Board. The collaborators undertook the task, alike laudable and arduous, of discovery and exposition of the sources and materials for an economic history of the United States. The work was divided into twelve sections which were assigned severally to as many investigators, and these were aided in turn by numerous assistants drawn chiefly from graduate schools of colleges and universities to which a majority of the collaborators were primarily attached.

Without going further into the details of the history of this department, since most of them are already recorded in the Year Books of the Institution, it may be said that the organization proved to be administratively unsatisfactory both to the Institution and to the board of collaborators. Hence, in conformity with mutual assent, the department was discontinued by resolution of the Trustees voted at their meeting of December 1916.

In justice to this department it is proper to state in this historical connection that three of the divisions have completed their reports, in whole or in part, and that these have been issued by the Institution during the past two years under the general title "Contributions to American Economic History," as publications Nos. 215A, 215B, and 215C. In addition to these more formal reports, elaborate indexes of the economic material in the documents of several states of the United States have been prepared for publication under the joint auspices of the department and the New York Public Library. The preparation of the manu-

script in this large enterprise has been entrusted to Miss Adelaide R. Hasse, of the Public Documents Division of the New York Public Library. The resulting volumes have been issued, under No. 85 of the Institution's series, for the States of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, New York, California, Illinois, Kentucky, Delaware, Ohio, and New Jersey, while a volume for Pennsylvania is in press. Quite naturally also the collaborators and their assistants have published in journals and other media many monographs and shorter papers auxiliary to the main project. A bibliography to these contributions has been prepared by Professor Farnam and printed copies may be obtained from him or from the Institution. Fortunately for the intrinsic merits of the project, it is to be continued under the auspices of a new organization composed chiefly of the original collaborators of the department.

THE INSTITUTION AND THE PUBLIC.

Reciprocity of Relations.

It is often openly asserted and more often tacitly assumed that an endowed altruistic organization acting under a state or a national charter may proceed without restrictions in the development of its work. Thus, in accordance with this view, the Institution is frequently congratulated on its supposed freedom from governmental control and on its supposed immunity from social restraint. But this view is neither consonant with fact nor consistent with sound public policy. All such organizations are properly subject not only to the literal constraints of their charters but also to the commonly more narrow though unwritten limitations imposed by contemporary opinion. The ideal to be sought by them in any case consists in a reciprocity of relations between the individual endowment on the one hand and the vastly larger and more influential public on the other hand. This ideal, however, like most ideals, is rarely fully attainable. Its existence and importance are, indeed, almost as rarely recognized. Hence, any new altruistic organization is apt to find itself oscillating between two extreme dangers: the one arising from action on the part of the organization prejudicial to public interests; the other arising from public expectations impossible of attainment and therefore prejudicial to the organization.

Happily for the Institution, neither of these extreme dangers has been seriously encountered. Its evolution has proceeded without surpassing charter limitations and without permanent hindrance from an aggregate of expectations certainly quite unparalleled in the history of research establishments. But while thus far it has been practicable to steer clear of the rocks and the shoals toward which enthusiastic friends even of the Institution would have it head, and to demonstrate the inappropriateness, the futility, or the impossibility of a large number of recurring suggestions for application of the Institution's income, there remains a multitude of subjects and objects of omnipresent importunity for which the Institution has furnished and apparently can furnish only general disappointment. Some references have been made occasionally in previous reports to these matters, but in general they have been ignored for the reason that they tend to waste energy in the production of nothing better than heat of controversy. A full enumeration and discussion of them would require nothing short of a volume, which would be of value probably only to our successors. There are two classes of them, however, presenting widely different aspects, which appear worthy of special mention in this connection and at the present unusual epoch in the intellectual development of mankind. These two classes find expression respectively in the perennial pleas of humanists for a larger share of the Institution's income and in the more persistently perennial pleas of aberrant types of mind for special privileges not asked for, and not expected by, the normal devotees to learning.

Claims of Humanists.

Whenever and wherever the rules of arithmetic are ignored, then and there will develop vagaries, misunderstandings, and errors of fact that only the slow processes of time can correct. Hence it was not simply natural but necessary that in the evolution of the Institution something like conflict surpassing the bounds of generous rivalry should arise between claimants whose aggregate of demands for application of income has constantly exceeded the endowment from which income is derived. Indeed, if the evidences of experience are to be trusted, there is scarcely a province in the world of abstract and in the world of applied knowledge which has regarded its needs as incommensurate with that entire income.

It was an inevitable consequence, therefore, of inexorable conditions that a majority of the commendably enthusiastic workers in these numerous provinces should fail to get from the Institution all the aid they desired. It was a similarly inevitable consequence of those conditions that some of these enthusiastic workers should attribute their disappointment to wrong causes. And it might likewise have been predicted with certainty that the largest share of the resulting disapprobation visited upon the Institution should come from the province of the humanists, not because they possess any property of superiority, of inferiority, or any other singularity, but, firstly, for the reason that they are more numerous in the aggregate than the devotees of all other provinces combined; and, secondly, for the less obvious but more important reason that the subjects and objects of their province are more numerous, more varied, more complex, and in general less well defined than the subjects and objects of any other province.

Concerning all these matters humanistic which have agitated academic circles especially for centuries, the administrative office of the Institution is naturally called upon to share in an extensive correspondence. Some of this is edifying, most of it is instructive, but a large if not the greater part of it appears to have been relatively fruitless in comparison with the time and the effort consumed. Why is this so? Or, is it only apparently and not actually so? May it not be due to the proverbially narrow, or possibly "materialistic," tendencies sometimes attributed to administrative officers? Much attention has been given to these inquiries with a view to securing answers free from personal bias and independent of administrative or other ephemeral restrictions. Essentially correct answers are furnished, it is believed, by the voluminous correspondence referred to, since it has supplied the data required for application of the objective methods of observation and experiment as well as the data for application of the subjective methods of a priori reasoning and historico-critical congruity.

An appeal to that correspondence shows, in the first place, that there is no consensus of opinion amongst professed humanists as to what the humanities are. It is well known, of course, by those who have taken the trouble to reflect a little, that the words humánistic and humanist are highly technical terms, more so, for example, than the term "moment of inertia," the full mechanical

and historical significance of which can only be understood by consulting Euler's "Theoria Motus Corporum Solidorum." Technically, the humanist is not necessarily humane, though fortunately for the rest of us he generally possesses this admirable quality; he needs only to be human. The distinction is well illustrated at one extreme by what Greg called the "false morality of lady novelists," which could doubtless be surpassed by the falser morality of male authors of fiction; and at another extreme by the merciful role of the physician in saving lives, or the equally merciful role of the engineer who builds bridges that will not fall down and kill folks, whose works, nevertheless, are often relegated by the humanist to the limbo of technology.

But these finer shades of verbal distinction which, with more or less elaboration, have come down to plague us from the days of the illustrious Alcuin and Erasmus, but with no such intent on their part, are less disconcerting than other revelations supplied by this expert testimony. It shows, in the second place, the surprising fact that some few humanists would restrict this field of endeavor to literature alone. From this minimum minimorum of content the estimates of our esteemed correspondents vary with many fluctuations all the way up to a maximum maximorum which would embrace all that is included in the comprehensive definition of anthropology to be found in the Standard Dictionary. Thus some eminent authorities would exclude from the humanities all of the ancient classics even, except their literatures. To such devotees philology, literary or comparative, has no interest; while archeology, classical or cosmopolitan, is of no more concern to them than comparative anatomy, which latter, by the way, is held in certain quarters to comprise the whole of anthropology. Equally confident groups of enthusiasts, on the other hand, animated by visions held essential to prevent our race from perishing, would, each in its own way, have the Institution set up boundaries to knowledge within which the humanities, as always hitherto, would play the dominant part but whose appropriateness of fixation would be immediately disputed by other groups. There would be, in fact, only one point of agreement between them, namely, that the Institution's income is none too large to meet the needs of any group. It should be observed in passing, however, in fairness to our friends the humanists, that they are not alone in their regressive efforts to establish metes and bounds

for advancing knowledge. Contemporary scientists have likewise pursued the same ignis fatuus with similarly futile results, as is best shown by the arbitrary and often thought-tight compartments into which science is divided by academies and royal societies. A sense of humor leads us to conclude that these likenesses between groups and assemblages thereof, still more or less hostile at times to one another, serve well to prove that the individuals concerned are human if not humanistic and that they all belong to the same genus if not to the same species.

In the third place, there is included in the extensive correspondence on which this section is mainly based a special contribution of letters furnished mostly by university presidents and professors and by men of letters selected with a view to excluding all those who might be suspected of any non-humanistic predilections. These letters were received as replies to a communication issued first during the year 1910, and occasionally since then, soliciting counsel from those well qualified to assist the Institution in determining how it may best promote research and progress in the humanities and how it may be relieved of the charge of unfairness toward them in the allotment of its income. The essential paragraphs in this communication are the following:

> Amongst other suggestions arising naturally in this inquiry is that of the desirability of something like a working definition of the term humanities. To the question What are the humanities? one finds a variety of answers, some of which seem much narrower than desirable.
>
> In order to get additional information on this subject and in order to make this part of the inquiry as concrete and definite as possible, I am sending copies of the inclosed list of publications to a number of friends requesting them to mark those entries of the list which they, as individuals, would consider works falling properly in the fields of the humanities. I shall esteem it a great favor, therefore, if you will kindly examine this list, indicating by some sort of check-mark what works, if any, may be rightly so classed, and then mail the same in the inclosed stamped envelope. It will be of service also, to indicate to me, if you care to do so, the lines of distinction which may be drawn between the humanistic sciences and the physical sciences. I am sure you will agree with me that it will be a decided aid to all of us to secure something like common definitions for these boundaries of knowledge.

About thirty distinguished authors have participated in this symposium; and their frank and generous expressions of opinion would be well worthy of publication if they had not been assured

that their responses would not be used for such a purpose. The identities and details of their letters must therefore be retained, for the present at any rate, in the archives of the Institution. But since many of them have offered to relieve the solicitor of this obligation, and probably all of them would do so on request, it is believed that no confidence will be violated in stating the two following statistical facts, which not only agree with one another but strongly confirm also the inductions referred to above, drawn from the more miscellaneous correspondence of the Institution:

1. The definitions of the term humanities vary from the exclusiveness of literature alone to the inclusiveness of the more recent definitions of anthropology, with a noteworthy tendency toward inclusiveness rather than the reverse.

2. To the concrete question What works, if any, already published by the Institution fall in the humanities, the answers vary from 2 to 33, the number of publications up to 1910 being 146.

The correspondent who assigned the largest number of publications to the humanities took the trouble also to count up the totals of the numbers of pages of all the works issued by the Institution up to that time. His count gave: for the humanities, 10,813 pages; for all other branches of knowledge, 21,700 pages.

In connection with these statistical data, it is appropriate to add the corresponding figures for the publications of the Institution brought down to date, namely, October 1917. In deriving these there are included under the humanities works in archeology, folk-lore, international law, history, literature, and philology. Of a total of 88 volumes, 58 octavos contain 19,921 pages and 30 quartos contain 10,718 pages, the total number of pages being 30,639; but four of the volumes are still in press and their pagination is not included.

Since the total number of pages of printed matter issued by the Institution up to date is 98,565, it appears that the shares, if such a term may be used, allotted to the humanities and to all other fields of learning combined are in round numbers one-third and two-thirds respectively. Whether this is one of fairness and fitness will doubtless remain for a long time a disputed question, since it seems to be one to which the dictum of Marcus Aurelius applies with peculiar emphasis. In the meantime, while waiting for a diminution in the diversity of opinion which calls that dictum to mind, it appears to be the duty of the Institution to pro-

ceed, as it has sought to proceed hitherto, in a spirit of sympathy and equity based on merit towards all domains of knowledge, with a full appreciation of the necessary limitations of any single organization and with a respectful but untrammeled regard for the views, the sentiments, and the suffrages of our contemporaries.

Aberrant Types of Mind.

If words and phrases drawn out of the past may obscure thought and supplant reason in the domains of the less highly developed sciences, like the humanities, for example, they are by no means free from difficulties when used as media for the communication of ideas in the domains of the more highly developed sciences. The differences between the ambiguities and the obscurities of the two domains are mainly in degree rather than in kind. It is a truism, of course, that in general it is much easier to discover errors and to improve uncertain verbal expression in the definite than in the indefinite sciences. Erroneous statements and interpretations of fact may be often corrected by the facts themselves or by means of a knowledge of their relations to underlying principles. Precision and correctness of language are also greatly increased in any department of learning when it becomes susceptible to the economy of thought and of expression characteristic of the mathematico-physical sciences. The perfection of these latter is, indeed, so great that novices working in them are often carried safely over hazardous ground to sound conclusions without adequate apprehension of the principles involved and with only erroneous verbal terms at command to designate the facts and the phenomena considered.

Nevertheless, it must be admitted that the terminology of what commonly passes for science as well as the terminology used frequently even by eminent men of science is sadly in need of reformation in the interests of clear thinking and hence of unequivocal popular and technical exposition. To realize the vagueness and the inappropriateness in much of the current use of this terminology one needs only to examine the voluminous literature available in almost any subject called scientific. It is so much easier to appear to write well, or even brilliantly, than it is to think clearly, that facile expression is often mistaken for sound thought. Thus, to illustrate, while in physics the terms force, power, and energy have acquired technical meanings entirely

distinct and free from ambiguity, they are commonly used as synonyms, and quite too commonly to designate properties, sentiments, and influences to which their application is meaningless. The "forces," the "powers," and more recently, the "energies" of "nature" are frequently appealed to in popular literature; and a familiar bathos consists in equipping them solemnly with the now vanishing stable furniture "for the benefit of mankind." Science is disfigured and hindered also by much inherited antithetical terminology for which reasons once existent have now disappeared or are disappearing. Instances are found in such terms as metaphysics, natural history, and natural science, the two latter of which appear to have come down to us without sensible modification, except for a vast increase in content, since the days of Pliny the Elder. The diversification and the resulting multiplication of meanings of the terms of science are everywhere becoming increasingly noticeable and confusing. One of the most recent manifestations is seen in the phrase "scientific and industrial research," which probably means about the same thing as the equally uncertain phrase "pure and applied science"; while both phrases have been turned to account in setting up invidious distinctions inimical to the progress of all concerned.

This looseness in the use of terminology inherited from our predominantly literary predecessors and the prevailing absence of any exacting standards of excellence in exposition make it easy for that large class here designated as aberrant types to take an unduly prominent part in the evolution of any establishment founded for the promotion of "research and discovery and the application of knowledge for the improvement of mankind." These types are numerous and each of them presents all gradations ranging from harmless mental incapacity up to aggressive pseudo-science, which latter often wins popular approval and thus eclipses the demonstrations of saner counsels. The representatives of these types are variously distinguished in common parlance as cranks, quacks, aliens, charlatans, mountebanks, etc. Some of the most persistent types are known as arc-trisectors, circle-squarers, and perpetual-motion men and women. They are not of recent development; they are coextensive with our race; but they have been little studied except in the cases of extreme divergency from the normal. One important work, however, has been devoted to the intermediate types of this class

with which the present section of this report is concerned. This is the profoundly learned book entitled "A Budget of Paradoxes,"* by Augustus De Morgan, who gave a surprising amount of attention, extending through several decades, to these people, whom he called "paradoxers."

It ought to be well known, but evidently is not, that the Institution has had to deal with, and must continue to be harassed by, great numbers of these aberrant types. The happy phrase of the Founder concerning the "exceptional man" has worked out very unhappily both for them and for the Institution, since it has only inevitable disappointment to meet their importunate demands, while they in turn have only inevitable animadversion to visit finally upon the Institution. Deluded enthusiasts and designing charlatans entertain alike the illusion that here at last is an establishment that will enable them to realize their wildest dreams of fame and fortune. But in the end the hopes of these people are either rudely shocked or wrecked, not because the Institution would disturb them in their fancies but because they compel the Institution to decline to approve their theories and to subsidize their projects. Many individuals of this class are extraordinarily clever, in literary capacity especially, although they are almost all notably deficient in critical faculties. In the initial stages of correspondence with them they are wont to attribute superhuman qualities to the administrative officer concerned, but if he becomes at all exacting they are wont to suggest a speedy degeneracy for him towards inhuman qualities. The absurdities, the arrogance, and the audacity (often pushed to the extreme of mendacity) of their claims are generally ludicrous enough, but these claims are often founded also on recondite fallacies which present pathetic as well as humorous aspects. Two illustrations drawn from the older and hence more impersonal sciences may suffice to indicate the nature of the daily experience here in question:

1. A teacher of youth in a public school desires assistance in securing letters-patent for a new proof of the Pythagorean theorem. And why not, since we read every day in the public press and in the debates of legislative bodies of "principles" being patented?

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*This was published originally in 1872. A second edition in two volumes, edited by Professor David Eugene Smith, has recently (1915) been issued by the Open Court Publishing Company, of Chicago and London.

2. Quite recently it has been "discovered" that the air and the ether contain "free energy." If this is so, if energy like urbanity is free, why should it not be rendered available at the expense of the Institution for the improvement of mankind?

Study and reflection concerning these aberrant types and an intimate association with them beginning thirty years before the foundation of the Institution, all point to the conclusion that responsibility for their undue prominence must be attributed in large degree and in the last analysis to a prevalent inadequate development of critical capacity even amongst the best educated classes of contemporary life. Many representatives of these latter regard the eccentric individual as thereby worthy of special attention. He is often referred to as a sprite or as a male witch, but commonly, of course, under the more familiar designations of our day as "a genius" or as "a wizard." Thus it is quite easy for obvious charlatans and ignoramuses, as well as for those in pursuit of Sisyphean paralogisms and anachronisms, to secure letters of introduction and commendation to the Institution from distinguished people, who pass the applicants along on the theory apparently that no harm can result from an effort to assist in the laudable work of extending learning. It is assumed that a research establishment must have effective facilities for utilizing the necromantic capacities attributed to those in particular to whom the terms genius and wizard are by common assent applied. Such introductions and commendations are generally held to be equivalent to approvals which may not be lightly set aside. The suggestion of tests of the pretensions and of checks on the deductions of these applicants is repulsive to them. What they desire is not diagnosis but indorsement. In all these matters there is revealed likewise a widely diffused misapprehension concerning the meanings of the terms science and research. The first may mean anything from occultism to the steam engine or to the telephone and thence up to those rarely appreciated principles of which the law of conservation of energy is one of the most conspicuous examples. The other term has a similarly wide range of meaning, but it stands most commonly either for a secret process which leads to riches by way of patent offices or for enterprises in which the Institution is supposed to act as a complaisant disbursing agency.

In dealing with these aberrant types there are encountered certain other fallacies of a more specious and hence of a more troublesome character. They arise out of the prevailing innocence of, if not contempt for, the doctrine of probabilities. The simplest of these fallacies is seen in the common belief that one mind is as likely as another to make discoveries and advances in the realms of the unknown. Thus it is assumed that research establishments should maintain experts, or corps of them, for the purpose of promoting the efforts of tyros, amateurs, and dilettanti, or, in other words, perform the functions of elementary schools. A subtler fallacy is expressed in the more common belief that a research organization should occupy itself chiefly in soliciting and in examining miscellaneous suggestions. It is held that if these are received in large numbers and if they are read long enough and hard enough, the possibilities of knowledge will be completely compassed. This has been elsewhere called the process of "casting dragnets in the wide world of thought . . . with the expectation that out of the vast slimy miscellanies thus collected there will be found some precious sediments of truth." It is, indeed, a metaphysical method of extracting truth out of error. The worst of all these fallacies is found in the not unpopular notion that if experts could be set at work under the direction of inexperts great progress could be achieved. This is the fallacy so often used to justify placing technical work under the administration of politicians and promoters rather than under the charge of competent men. It finds frequent expression also in suggestions to the Institution that its corps of investigators might avoid the dangers of "respectable mediocrity" by yielding to the requests of the less conservative and more brilliant advocates of advancing knowledge.

But what, it may be asked, are the characteristics which differentiate these pseudo-scientists from normal investigators? They are well defined and not numerous. The pseudo-scientist is in general excessively egoistic, secretive, averse to criticism, and almost always unaware of the works of his predecessors and contemporaries in the same field. He displays little of that caution which is born of adequate knowledge. He is lacking especially in capacity to discover and to correct his own mistakes. He is forever challenging others to find errors in his work. He

has an overweening confidence often in formal logic, but is unable to see that this useful device may play tricks by bringing him, for example, simultaneously to right and to wrong conclusions by reason of wrong premises. His worst defect is manifested in asking for and in expecting to get more lenient consideration in the forum of demonstration than that accorded to his more modest but more effective competitors.

How inadequate are the hasty popular estimates of these exceptional individuals is sufficiently witnessed in the extensive experience of the Institution. In the brief interval of its existence it has had to deal with about 12,000 of them. Many of these have been commended to the Institution in terms well calculated to set aside the laws of biologic continuity and thus to elevate the aspirants abruptly from irreproachable respectability to questionable fame. To some of them have been attributed qualities worthy of the mythological characteristics conceived by the unrestrained imaginations of men in prescientific times. Not a few of them have proved to be obvious fakers, schemers, or incompetents masquerading in the name of learning with the confident expectation that the Institution would indorse, finance, or otherwise promote their objects under the guise of research. But, as might have been predicted, the history of all this varied experience is a history of futility clouded here and there by manifestations of the baser traits of mankind and lighted up only occasionally by flashes of wit, wisdom, or humor in the prevailing pathologic cast.

RESEARCHES OF THE YEAR.

Departments of Research.

In spite of the disturbing conditions by which the world has been confronted during the past three years, the researches of the Institution have proceeded, in general, without essential modifications or limitations. Thus, while the complexities of these conditions and the uncertainties they entail have increased in marked degree, there has been as yet no corresponding diminution in the productive capacities of the departments of research. Many circumstances have arisen to change the incidence and to enlarge the scope of their activities, but all these have remained within the limits of their respective fields of investigation. It is a significant fact in respect to these activities that there is now manifest not only an increasing public appreciation of the knowledge developed by these departments, but also an increasing public demand

for men and for methods essential in the production of such knowledge. A natural result of this demand has been a loss to the departments during the year of some of their ablest men, who have been offered superior opportunities with commercial, educational, or other organizations. Such losses are compensatory, however. They are normal and necessary to a progressive establishment in an aggressive age. One of the highest functions the Institution can fulfill is the development of men whose expert qualifications fit them to meet the expanding needs of other positions and organizations.

An examination of the departmental reports to be found in the current Year Book and of the bibliographic appendix following this report will show that progress has been maintained in all principal projects, and that these are likely to go forward without serious delays in the immediate future. A similar examination at some future epoch of the current proceedings of these departments and of the correspondence with them will furnish materials for an instructive chapter in any comprehensive history of the Institution.

Division of Research Associates.

What is said above in respect to the departments of research applies without sensible qualifications to the activities of the division of research associates. Their varied investigations have been carried on, in the main, with the customary zeal and fertility, as may be seen by reference to their reports of current progress in the Year Book and to the annual bibliography of contributions to journals and to the more formal publications of the Institution itself. With them, however, as with the staffs of the departments of research, many new duties for which their training and experience have specially qualified them have been assumed; so that they, likewise, are contributing data for the future historian of the parts played by representatives of the Institution in the fateful drama of passing events.

FINANCIAL RECORDS.

Financial Statement for Fiscal Year 1916–1917.

The sources of funds available for expenditure during the past fiscal year, the allotments for the year, the revertments made during the year, and the balances unallotted at the end of the year are shown in detail in the following statement:

Financial Statement for fiscal year 1916–1917.

Object of appropriation.	Balances unallotted Oct. 30, 1916.	Appropriation Dec. 15, 1916.	Revertments Nov. 1, 1916, to Oct. 31, 1917.	Total.	Aggregates of allotments and amounts transferred.	Balances unallotted Oct. 31, 1917.
Large grants...	....	$698,731	$20,329.84	$719,060.84	$719,060.84	....
Minor grants...	$3,855.20	110,560	100.00	114,515.20	112,336.67	$2,178.53
Publication....	15,256.77	60,000	33,456.89	108,713.66	90,029.06	18,684.60
Administration.	....	53,060	10,000.00	63,060.00	63,060.00	....
Reserve fund...	....	250,000	....	250,000.00	250,000.00	....
Insurance fund.	....	25,000	....	25,000.00	25,000.00	....
Departments and divisions of research...	....	*84,350	....	84,350.00	84,350.00	....
Salary increases, 1917........	....	†5,908	....	5,908.00	5,908.00	....
Total........	19,111.97	1,287,609	63,886.73	1,370,607.70	1,349,744.57	20,863.13

*Balance of $100,000 special appropriation: Assignments, large grants, $15,650.

†Balance of $50,000 special appropriation: Assignments, large grants, $39,272; minor grants, $1,760; administration, $3,060.

Summary of Receipts and Expenditures of the Institution to date.

The aggregates of receipts from interest on endowment, from interest on bond investments, from interest on deposits in banks, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution, are shown by the following table; the grand total of these to date is $14,433,327.92.

Aggregates of financial receipts.

Year ending Oct.31.	Interest on endowment.	Interest on bonds and bank deposits.	Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
1902..	$250,000.00	$9.70	....	....	$1,825.52	$251,835.22
1903..	500,000.00	5,867.10	$2,286.16	....	101.57	508,254.83
1904..	500,000.00	33,004.26	2,436.07	$999.03	....	536,439.36
1905..	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906..	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907..	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908..	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909..	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910..	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911..	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912..	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913..	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914..	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915..	1,100,375.00	67,888.31	10,297.79	8,322.87	28,162.79	1,215,046.76
1916..	1,100,375.00	83,626.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917..	1,100,408.75	100,702.60	11,921.35	32,950.22	179,611.97	1,425,594.89
Total.	12,084,597.92	561,177.73	128,429.54	69,666.42	*1,589,456.31	14,433,327.92

*Of this amount $1,344,335 came from the sale of bonds in 1908, 1909, 1910, 1912, 1913, 1914, 1915, 1916, 1917; $51,265.74 from Colburn Estate in 1916; and $170,000 from Carnegie Corporation of New York in 1917.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads: (1) investments in bonds; (2) large projects; (3) minor projects, special projects, and research associates and assistants; (4) publications; (5) administration. The following table shows the actual expenditures under these heads for each year since the foundation of the Institution:

Purposes for which funds have been appropriated.

Year ending Oct. 31.	Investments in bonds.	Large projects.	Minor projects, special projects, research associates, and assistants.	Publications.	Administration.	Total.
1902.	....	....	$4,500.00	....	$27,513.00	$32,013.00
1903.	$100,475.00	....	137,564.17	$938.53	43,627.66	282,605.36
1904.	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905.	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906.	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907.	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908.	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909.	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910.	57,889.15	437,941.40	73,464.63	49,067.00	44,011.61	662,373.79
1911.	51,921.79	463,609.75	63,048.80	37,580.17	45,455.80	661,616.31
1912.	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913.	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914.	861,915.73	817,894.52	107,456.05	44,670.55	44,159.54	1,876,096.39
1915.	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916.	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917.	505,473.49	695,813,07	97,526.69	62,884.61	48,776.29	1,410,464.15
Total.	3,858,363.50	7,187,775.85	1,588,531.24	644,017.62	694,936.36	13,973,614.57

The following list shows the departments of investigation to which the larger grants were made by the Trustees at their last annual meeting and the amounts allotted from these grants by the Executive Committee during the year:

Department of Botanical Research	$43,430.00
Board of Collaborators in American Economic History (transferred from the balance to the credit of the former Department of Economics and Sociology)	16,829.84
Department of Embryology	34,772.00
Department of Experimental Evolution	56,929.00
Geophysical Laboratory	101,508.00
Department of Historical Research	35,450.00
Department of Marine Biology	19,900.00
Department of Meridian Astrometry	31,156.00
Nutrition Laboratory	46,134.00
Division of Publications	11,202.00
Solar Observatory	177,544.00
Department of Terrestrial Magnetism	142,206.00
Total	717,060.84

The following statements show the fields of investigation to which minor grants were assigned, together with the names of the grantees and the amounts of the grants; also the grants for publications authorized during the year.

Details of minor grants.

Fields of investigation.	Names of grantees.	Amounts of grants.
Anthropology	Bandelier Manuscripts, preparation	$2,600.00
Astronomy	Kapteyn, J. C.	2,000.00
Archeology	Van Deman, E. B.	2,310.00
	Morley, S. G.	5,840.00
Bibliography	Index Medicus	12,000.00
Biology	Crampton, H. E.	2,000.00
	Morgan, T. H.	3,300.00
Botany	Clements, F. E.	4,916.67
Chemistry	Morse, H. N., and J. C. W. Frazer	3,600.00
	Noyes, A. A.	2,700.00
	Osborne, T. B., and L. B. Mendel	15,000.00
	Richards, T. W.	2,700.00
	Sherman, H. C.	1,080.00
	Smith, Edgar F.	1,500.00
	Remsen, Ira	1,500.00
Geology	Chamberlin, T. C.	3,600.00
	Moulton, F. R.	1,800.00
Geophysics	Wahl, Walter	2,000.00
History	Osgood, H. L.	1,800.00
Literature	Bergen, Henry	1,800.00
	Tatlock, J. S. P.	1,800.00
Mathematics	Morley, Frank	1,080.00
Meteorology	Bjerknes, V.	1,800.00
Paleontology	Case, E. C.	1,500.00
	Hay, O. P.	3,300.00
	Wieland, G. R.	3,300.00
Philology	Churchill, William	5,500.00
Paleography	Loew, E. A.	2,310.00
Physics	Barus, Carl	500.00
	Hayford, J. F.	1,800.00
	Howe, H. M.	500.00
	Nichols, E. L.	3,000.00
Political Science	Rowe, L. S.	800.00
Zoology	Castle, W. E.	2,500.00
Department of Meridian Astrometry		700.00
Carnegie Institution of Washington (actuarial data)		500.00
		104,936.67

Grants for publications authorized during the year.

Barus, Carl	$1,200.00
Benedict, F. G., and T. M. Carpenter	2,200.00
Bergen, Henry	4,000.00
Britton, N. L., and J. N. Rose	10,000.00
Carnegie Institution of Washington Pamphlets	66.42
Churchill, William	1,800.00
Contributions to Embryology	2,400.00
Crampton, Henry E	1,153.81
Davenport, C. B	4,000.00
Davenport, F. G	2,000.00
Davis, Paul B	1,400.00
Dickson, L. E	2,800.00
Howard, L. O	2,335.97
Huntington, E	42.07
Mayer, A. G., *et al*	4,000.00
Meyer, B. H	941.93
Muller, W. Max	2,000.00
Riddle, Oscar	7,200.00
Republication of Classics of International Law	3,615.99
Researches, Department of Terrestrial Magnetism	2,606.21
Rowe, L. S	900.00
Sommer, H. O	70.00
Streeter, G. L	1,800.00
Tower, W. L	5,800.00
Weed, L. H	696.66
	65,029.06

Investments in Property. On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended since the foundation of the Institution:

*Schedule of real estate, equipments, and publications.**

Administration:		
Building, site and equipment		$332,935.45
Department of Botanical Research (Sept. 30, 1917):		
Buildings and grounds	$29,693.91	
Laboratory and library	13,896.46	
Operating appliances	17,883.86	
		61,474.23
Department of Experimental Evolution (Sept. 30, 1917):		
Buildings, office, and library	110,261.80	
Laboratory apparatus	8,326.10	
Operating appliances and grounds	21,687.00	
		140,274.90
Geophysical Laboratory (Sept. 30, 1917):		
Building, library, operating appliances	166,295.91	
Laboratory apparatus	69,761.25	
Shop equipment	10,156.16	
		246,213.32
Department of Historical Research (Sept. 30, 1917):		
Office	2,221.47	
Library	3,145.94	
		5,367.41
Department of Marine Biology (Sept. 30, 1917):		
Vessels	32,944.40	
Buildings, docks, furniture, and library	11,967.96	
Apparatus and instruments	6,727.31	
		51,639.67
Department of Meridian Astrometry (Sept. 30, 1917):		
Apparatus and instruments	2,394.34	
Operating	1,544.62	
		3,938.96
Forward		841,843.94

*Real estate and equipment, original cost.

Schedule of real estate, equipments, and publications—Continued.

Brought forward		$841,843.94
Nutrition Laboratory (Sept. 30, 1917):		
Building, office, and shop	119,538.27	
Laboratory apparatus	23,111.79	
		142,650.06
Mount Wilson Solar Observatory (Aug. 31, 1917):		
Buildings, grounds, road, and telephone line	205,164.98	
Shop equipment	37,329.56	
Instruments	414,218.56	
Furniture and operating appliances	88,770.86	
Hooker 100-inch reflector	492,177.46	
		1,237,661.42
Department of Terrestrial Magnetism (Sept 30, 1917):		
Building, site, and office	132,529.59	
Vessel and survey equipment	129,143.91	
Instruments, laboratory, and shop equipment	63,291.17	
		324,964.67
		2,547,120.09
Publications:		
Stock on hand at sale price (Oct. 31, 1917)	263,472.80	
Outstanding accounts (Oct. 31, 1917)	1,708.17	
		265,180.97
		2,812.301.06

Expenses of Maintenance of Administration Building.

The cost of maintenance of the Administration Building, including the items of fuel, lighting, janitorial services, maintenance of grounds, repairs, and other incidental expenses, has been, for 1910, $2,981.65; for 1911, $2,641.53; for 1912, $2,919.89; for 1913, $2,601.15; for 1914, $3,251.08; for 1915, $3,955.60; for 1916, $2,870.51, and for 1917, $3,272.50.

PUBLICATIONS.

Publications Authorized and Issued during the Year.

The publication of 25 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of $65,029.06. The following list gives the titles and names of the authors of the publications issued during the year; it includes 21 volumes, with an aggregate of 4,464 octavo pages and 2,691 quarto pages; 27 additional volumes are now in press.

List of publications issued during the year.

Year Book, No. 15, 1916. Octavo, 422 pages, 1 plate, 3 figures.

Index Medicus, Second Series, vol. 14, 1916. Octavo, 1010 pages.

No. 159. Howard, L. O., Harrison G. Dyar, and Frederick Knab. The Mosquitoes of North and Central America and the West Indies. In 4 volumes. Vol. 4. Systematic Description, Part II. Octavo, pages 525 to 1064.

No. 175. Bauer, L. A., in collaboration with W. J. Peters, J. A. Fleming, J. P. Ault, and W. F. G. Swann. Ocean Magnetic Observations, 1905–1916, and Reports on Special Researches. (Researches of the Department of Terrestrial Magnetism. Vol. III.) Quarto, vii + 447 pages, 24 plates, 35 figures.

No. 208. Broughton, L. N., M. R. Thayer, and others. A Concordance to the Poems of Keats. Quarto, xxi + 437 pages, 1 plate.

No. 215C. History of Transportation in the United States before 1860. Prepared under the direction of Balthasar Henry Meyer by Caroline E. MacGill and a staff of Collaborators. Octavo, x + 678 pages, 5 plates.

List of publications issued during the year—Continued.

No. 224. Contributions to Embryology, Nos. 10, 11, 12, 13. Quarto, 106 pages.
- Mall, F. P. The Human Magma Reticule in Normal and in Pathological Development. (Contribution No. 10.) 22 pages, 3 plates.
- Cowdry, E. V. The Structure of Chromophile Cells of the Nervous System. (Contribution No. 11.) 18 pages, 1 plate.
- Cunningham, R. S. On the Development of the Lymphatics of the Lungs in the Embryo Pig. (Contribution No. 12.) 24 pages, 5 plates.
- Macklin, Charles C. Binucleate Cells in Tissue Cultures. (Contribution No. 13.) 38 pages, 70 figures.

No. 225. Weed, Lewis H. Development of the Cerebro-Spinal Spaces in Pig and in Man. (Contribution to Embryology No. 14.) Quarto, 116 pages, 17 plates.

No. 226. Contributions to Embryology, Nos. 15, 16, 17, 18, 19. Quarto, 168 pages.
- Mall, F. P. Cyclopia in the Human Embryo. (Contribution No. 15.) 29 pages, 3 plates, 7 figures.
- Thurlow, Madge De G. Quantitative Studies on Mitochondria in Nerve-Cells. (Contribution No. 16.) 10 pages, 1 plate.
- Lewis, Margaret Reed. Development of Connective Tissue Fibers in Tissue Cultures of Chick Embryos. (Contribution No. 17.) 16 pages, 2 plates.
- Sabin, Florence R. Origin and Development of the Primitive Vessels of the Chick and of the Pig. (Contribution No. 18.) 64 pages, 7 plates, 8 figures.
- Johnson, Franklin Paradise. A Human Embryo of Twenty-four pairs of Somites. (Contribution No. 19.) 42 pages, 8 plates, 9 figures.

No. 228. Crampton, Henry E. Studies on the Variation, Distribution, and Evolution of the Genus Partula: The Species Inhabiting Tahiti. Quarto, 313 pages, 34 plates, 7 text figures.

No. 234. Hill, Roscoe R. Descriptive Catalogue of the Documents relating to the History of the United States in the Papeles Procedentes de Cuba, deposited in the Archivo General de Indias at Seville. Octavo, XLIII + 594 pages.

No. 239. Golder, Frank A. Guide to Materials for American History in Russian Archives. Octavo, VIII + 177 pages.

No. 243. Goodale, H. D. Gonadectomy in relation to the Secondary Sexual Characters of Some Domestic Birds. (Paper No. 27, Station for Experimental Evolution.) Octavo, 52 pages, 7 plates.

No. 244. Churchill, William. Sissano: Movements of Migration within and through Melanesia. Octavo, 181 pages, 17 charts.

No. 249. Barus, Carl. The Interferometry of Reversed and Non-reversed Spectra. Octavo, 158 pages, 99 figures.

No. 250. Knobel, Edward B. Ulugh Beg's Catalogue of Stars, revised from all Persian manuscripts existing in Great Britain, with a vocabulary of Persian and Arabic words. Quarto, 109 pages, 1 plate.

No. 251. Papers from the Department of Marine Biology of the Carnegie Institution of Washington. Vol. XI. Octavo, v + 360 pages, 20 plates, 59 figures.
- Mayer, Alfred G. Nerve-conduction in Cassiopea xamachana. 20 pages, 15 figures.
- McClendon, J. F., C. E. Gault, and S. Mulholland. The Hydrogen Ion Concentration, CO_2 Tension, and CO_2 Content of Sea-water. 48 pages, 24 figures.
- Goldfarb, A. J. Variability of Eggs and Sperm of Sea-urchins. 16 pages.
- Hatai, S. On the Composition of the Medusa Cassiopea xamachana. 14 pp., 1 fig.
- Phillips, A. H. Analytical Search for Metals in Tortugas Marine Organisms. 4 pages.
- Cary, L. R. Studies on the Physiology of the Nervous System of Cassiopea xamachana. 49 pages, 18 figures.
- Clark, H. L. The Habits and Reactions of a Comatulid, Tropiometra carinata. 8 pp.
- Harvey, E. Newton. The Chemistry of Light-production in Luminous Organisms. 63 pages, 1 figure.
- Harvey, Ethel Browne. A Physiological Study of Specific Gravity and of Luminescence in Noctiluca, with special reference to Anesthesia. 18 pages.
- Treadwell, A. L. Polychætous Annelids from Florida, Porto Rico, Bermuda, and the Bahamas. 13 pages, 3 plates.
- Jordan, H. E. Microscopic Structure of Striped Muscle of Limulus. 17 pp., 3 plates.
- Jordan, H. E. Hemopoiesis in the Mongoose Embryo, with special reference to the Activity of the Endothelium, including that of the Yolk-sac. 11 pages, 4 plates.
- Jordan, H. E. Embryonic History of the Germ-cells of the Loggerhead Turtle, Caretta caretta. 31 pages, 6 plates.
- Jordan, H. E. Atresia of the Esophagus in the Loggerhead Turtle Embryo, Caretta caretta, a Normal Development Condition. 15 pages, 4 plates.

List of publications issued during the year—Continued.

No. 255. Churchill, William. Club Types of Nuclear Polynesia. Octavo, v+173 pages, 17 plates, 3 figures.

Illustrated pamphlet, entitled "The Carnegie Institution of Washington, Scope and Organization." Sixth issue, dated February 28, 1917. Octavo, 49 pages.

Classics of International Law:

Victoria, Franciscus de: De Indis et de Ivre Belli Relectiones.

Introduction by Ernest Nys, and Translation (by John Pawley Bate) of the Introduction by Ernest Nys. Pages 9–100.

A Translation of the Text, by John Pawley Bate. Pages 101–187.

Revised Text by Herbert Francis Wright. Pages 189–297.

A Photographic Reproduction of Edition of 1696. Pages 299–476.

Legnano; Giovanni da: Tractatus De Bello, de Represaliis et de Duello. Edited by Thomas Erskine Holland. Quarto, xxxiii+458 pages, 1 plate.

Sales of Publications and Value of those on hand. The following table shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution:

Table showing sales of publications.

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903...	$2,256.91	$29.25	....
1904...	2,370.47	52.85	$12.75
1905...	2,562.76	44.75	431.44
1906...	2,970.56	37.60	1,341.52
1907...	3,676.71	56.50	2,292.89
1908...	3,406.19	99.65	4,371.67
1909...	4,821.85	73.01	6,287.21
1910...	4,470.50	100.70	5,899.05
1911...	4,440.21	85.50	6,366.55
1912...	4,652.14	61.65	6,782.34
1913...	4,992.02	75.95	7,140.69
1914...	5,079.16	49.65	6,273.59
1915...	5,010.21	47.60	5,239.98
1916...	4,382.19	46.60	8,115.37
1917...	4,616.21	51.55	7,253.59
Total.	59,708.09	912.81	67,808.64

At the end of the fiscal year there are on hand 97,407 volumes of miscellaneous publications and Year Books, having a sale value of $246,012.05; also 32,984 numbers of the Index Medicus, having a sale value of $17,460.75. The total value of publications on hand is therefore $263,472.80.

In connection with the above statement it is fitting to add that since the foundation of the Institution there have been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent also by sales, a total of 165,888 volumes of publications of the Institution.

Growth and Extent of Institution's Publications. The data furnished in the following table are of statistical interest in respect to the work of publication of the Institution. Three hundred and fifty-five volumes, embracing a total of 98,565 pages of printed matter, have thus far been issued by the Institution.

Table showing number of volumes, number of pages (octavo and quarto), and totals of pages of publications issued by the Institution for each year and for the sixteen years from 1902 to 1917.

Year.	Number of volumes issued.	Number of octavo pages.	Number of quarto pages.	Total number of pages.
1902.....	3	46	......	46
1903.....	3	1,667	......	1,667
1904.....	11	2,843	34	2,877
1905.....	21	3,783	1,445	5,228
1906.....	19	3,166	1,288	4,454
1907.....	38	6,284	3,428	9,712
1908.....	28	4,843	2,485	7,328
1909.....	19	3,695	1,212	4,907
1910.....	29	3,274	4,831	8,105
1911.....	30	5,062	1,670	6,732
1912.....	23	3,981	2,044	6,025
1913.....	29	6,605	2,752	9,357
1914.....	23	4,978	1,934	6,912
1915.....	23	4,686	1,466	6,152
1916.....	35	9,478	2,430	11,908
1917.....	21	4,464	2,691	7,155
Total...	355	68,855	29,710	98,565

APPENDIX.

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK OF INVESTIGATORS, ASSOCIATES, AND COLLABORATORS.

Under this heading it is sought to include titles of all publications proceeding from work done under the auspices of the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (pp. 33-35).

Adams, Walter S. Note on Barnard's large proper-motion star. Pubs. A. S. P., vol. 28, 278 (1916).

———. Some recent spectral parallax determinations. Pubs. A. S. P., vol. 28, 279 (1916).

———, and Alfred H. Joy. Note on the spectrum of *o* Ceti. Pubs. A. S. P., vol. 29, 112 (1917).

———, ———. Two stars with bright hydrogen lines. Pubs. A. S. P., vol. 29, 112 (1917).

———, ———. Five spectroscopic binaries. Pubs. A. S. P., vol. 29, 113 (1917).

———, ———. The spectra of some double stars. Pubs. A. S. P., vol. 29, 182 (1917).

———, and Gustaf Strömberg. The relationship of stellar motions to absolute magnitude. Astrophys. Jour., vol. 45, 293–305 (1917); Mt. Wilson Contr., No. 131.

Allen, E. T., and Robert H. Lombard. A method for the determination of dissociation pressures of sulphides, and its application to covellite (CuS) and pyrite (FeS_2). Amer. Jour. Sci., No. 4, vol. xliii, 175–195 (1917).

Anderson, John A. A method of investigating the Stark effect for metals, with results for chromium. Astrophys. Jour., vol. 46, 104–116 (1917); Mt. Wilson Contr., No. 134.

———. A study of the Stark effect. Read at Stanford meeting, Amer. Phys. Soc. (1917); [Abstract] Phys. Rev., ser. 2, vol. 9, 575 (1917).

Anderson, Olaf. Aventurine labradorite from California. Amer. Mineralogist, vol. 2, 91 (1917).

Andrews, Charles M. The Boston merchant and the non-importation movement. Colonial Soc. Mass., vol. xix. [Reprint issued May 1917.]

Ault, J. P. Magnetic declinations observed on the *Carnegie* from Samoa to Guam and San Francisco, June-September, 1916. Terr. Mag., vol. 21, No. 4, 175–176 (Dec. 1916).

———. Preliminary results of ocean magnetic observations on the *Carnegie* from San Francisco to Easter Island and Buenos Aires, Nov. 1916–March 1917. Terr. Mag., vol. 22, No. 3, 139–144 (Sept. 1917).

———. See Bauer, L. A.

Avery, B. T. See Blakeslee, A. F.

Babcock, E. B. See Carpenter, T. M.

Babcock, Harold D., and Charles E. St. John. Elimination of pole effect from secondary standards of wave-length. Read at Stanford meeting, Amer. Phys. Soc. (1917); [Abstract] Phys. Rev., ser. 2, vol. 9, 577 (1917).

———. See St. John, Charles E.

Banta, A. M. Sex intergrades in a species of Crustacea. Proc. Nat. Acad. Sci., vol. 2, 578–583 (Oct. 1916).

———. A sex intergrade strain of Cladocera. Proc. Soc. Exp. Biol. Med., vol. 14, No. 1, 3–4 (Oct. 18, 1916).

———. A strain of sex intergrades. Anat. Rec., vol. xi, No. 6, 505–506 (Jan. 1917).

Bartelmez, G. W. See Evans, H. M.

Barus, Carl. Displacement interferometry of long distance. Proc. Nat. Acad. Sci., vol. 3, 436–437 (1917).

———. Measurement of small angles by displacement interferometry. Proc. Nat. Acad. Sci., vol. 3, 412–415 (1917).

———. Note on complementary Fresnellian fringes. Proc. Nat. Acad. Sci., vol. 3, 432–436 (1917).

———. Methods in reversed and non-reversed spectrum interferometry. Amer. Jour. Sci., vol. xlii, 402–420 (1916), vol. xliii, 145–162 (1917).

———. Refractivity determined irrespective of form. Proc. Nat. Acad. Sci., vol. 3, 117–122 (1917).

———. Interferometer methods based on the cleavage of the diffracted ray. Proc. Nat. Acad. Sci., vol. 2, 475–478 (1916).

———. Rotation of interference fringes. Amer. Jour. Sci., vol. xlii, 63–73 (1916).

———. Interferences of spectra, both reversed and inverted. Proc. Nat. Acad. Sci., vol. 2, 576–578 (1916).

Bauer, L. A. Concerning the origin of the Earth's magnetic field. [Abstract] Jour. Wash. Acad. Sci., vol. 6, No. 18, 635–636 (Nov. 4, 1916).

Bauer, L. A. The Earth's magnetism. The discoveries of Halley's expedition and recent investigations. [Abstracts from the fourth "Halley lecture" delivered in the schools of the University of Oxford on May 22, 1913; illustrated by lantern slides. Reprinted, after revision by the author, and with added illustrations, from Bedrock, vol. 2, No. 3, Oct. 1913, 273–294, in Smithsonian Report for 1913.] Sci. Amer. Sup., vol. 83, No. 2149, 156–159 (Mar. 10, 1917).

———. Some results of the ocean scientific work of the Department of Terrestrial Magnetism. [Abstract] Pop. Astron., vol. 25, No. 5, 308 (May 1917).

———. Remarks on the compass in aeronautics. Proc. Amer. Phil. Soc., vol. 56, 255–257 (June 21, 1917).

———. William Bullock Clark. Portrait and biographical sketch. Terr. Mag., vol. 22, No. 3, 147 (Sept. 1917).

———. A brief statement of the work of the Committee on Navigation and Nautical Instruments of the National Research Council. [Abstract.] Pop. Astron., vol. 25, No. 8, 520–521 (Oct. 1917).

Bichowsky, F. Russell von. The electrometric titration of zinc with ferrocyanide. Jour. Wash. Acad. Sci., vol. 7, 141–143 (1917).

———. The electrometric titration of zinc. Jour. Ind. Eng. Chem., vol. 9, 668–671 (1917).

Bidwell, C. C. Resistance and thermo-electric relations in iron oxide. Phys. Rev., No. 2, vol. viii, 12 (1916).

Bjerknes, V. Theoretisch-meteorologische Mitteilungen. Meteorol. Zeitsch., 166–176 (1917).

———. See Sverdrup, H. U.

Blakeslee, A. F. Corn and education. Jour. Hered., vol. viii, 51–57 (Feb. 1917).

———, and B. T. Avery. Adzuki beans and jimson weeds. Jour. Hered., vol. viii, 125–131 (Mar. 1917).

———. See Harris, J. Arthur.

Boss, Benjamin. A convergent point for four clusters of small proper-motion stars, Astron. Jour., No. 699 (Oct. 1916).

Bowen, N. L. The sodium-potassium nephelites. Amer. Jour. Sci., No. 4, vol. xliii., 115–132 (1917).

———. The problem of the anorthosites. Jour. Geol., vol. 25, 209–243 (1917).

———. Adirondack intrusives. Jour. Geol., vol. 25, 509–512 (1917).

Bridges, Calvin C. The elimination of males in alternate generations of sex-controlled lines. Anat. Rec., vol. xi, 504 (Jan. 1917).

———. An intrinsic difficulty for the variable force hypothesis of crossing over. Amer. Nat., vol. li, 370–373 (June 1917).

———. Deficiency. Genetics, vol. 2, No. 5 (Sept. 1917).

Burdick, C. L., and J. H. Ellis. The structure of chalcopyrite determined by X-rays. Proc. Nat. Acad. Sci. (1917).

Burnett, E. C. Ciphers of the Revolutionary Period. Amer. Hist. Rev., vol. xxii, 329–334.

Cannon, W. A. Relation of the rate of root growth in seedlings of *Prosopis velutina* to the temperature of the soil. Plant World, vol. 20 (Oct. 1917).

Carpenter, T. M. Physiological effects of ethyl alcohol when injected into the rectum, with special reference to the gaseous exchange. Amer. Jour. Physiol., vol. xlii, 605 (1917).

———, and E. B. Babcock. The absorption of alcohol and its concentration in the urine when injected by rectum. Jour. Biol. Chem., vol. xxix, Proc. Soc. Biol. Chem., xxviii (1917).

Carter, Edna. See King, Arthur S.

Cary, Lewis R. The influence of the marginal sense-organs on metabolic activity in *Cassiopea xamachana* Bigelow. Proc. Nat. Acad. Sci., vol. 2, No. 12, 709–712 (1916).

———. The influence of the marginal sense-organs on functional activity in *Cassiopea xamachana*. Anat. Rec., vol. ii, No. 6, 527–530 (1917).

———. The part played by the *Alcyonaria* in the formation of some Pacific coral reefs. Proc. Nat. Acad. Sci., vol. 3 (1917).

Case, E. C. Further evidence bearing on the age of the Red Beds in the Rio Grande Valley, N. M. Science, n. s., vol. xliv, No. 1142, 708–709 (Nov. 17, 1916).

———. The environment of the amphibian fauna at Linton, Ohio. Amer. Jour. Sci., vol. xliv, 124–136, 2 figs. (Aug. 1917).

Castle, W. E. Tables of linkage intensities. Amer. Nat., vol. l, 575–576 (Sept. 1916).

———. Piebald rats and multiple factors. Amer. Nat., vol. li, 102–114 (Feb. 1917).

———. The role of selection in evolution. Jour. Wash. Acad. Sci., vol. 7, No. 12, 369–387 (June 19, 1917).

———. Genetics and eugenics, a text-book for students of biology and a reference book for animal and plant breeders. Harvard Univ. Press, 353 pp., illustrated (Dec. 1916).

Clements, F. E. Evaporation and succession. Plant World (Aug. 1917).

———, and E. S. Clements. Field edition, Rocky Mountain flowers. (June 1917.)

Coble, A. B. Point sets and Cremona groups: Part III. Trans. Amer. Math. Soc., vol. xviii (July 1917).

Cunningham, R. S. See Shipley, P. G.

Dahlgren, Ulric. Production of light by the lower insects. Jour. Franklin Inst., 79–95, 9 figs. (Jan. 1917).

Dahlgren, Ulric. Production of light by the elaterid beetles. Jour. Franklin Inst., 211–222, 7 figs. (Feb. 1917).
———. Production of light by the lampyrid beetles. Jour. Franklin Inst., 323–349, 23 figs. (Mar. 1917).
———. Production of light by the Cephalochordata. Jour. Franklin Inst., 422–451, 10 figs. (Apr. 1917).
———. Production of light by the tunicates and Elasmobranch fishes. Jour. Franklin Inst., 735–755, 10 figs. (June 1917).
Davenport, C. B. The hereditary factor in pellagra. Arch. Internat. Med., vol. xviii, 1–29, figs. 38 (July 1916); Eugenics Record Office Bull. No. 16.
———. Eugenics as a religion. Paper read at Golden Jubilee Celebration of the Battle Creek Sanitarium, 8 pp. (Oct. 1916).
———. The personality, heredity, and work of Charles Otis Whitman, 1843–1910. Amer. Nat., vol. li, 5–30 (Jan. 1917).
———. The effect of race intermingling. Proc. Amer. Phil. Soc., vol. lvi, 364–368 (Apr. 1917).
———. Introduction to "Survey of mental disorders in Nassau County, New York, July-October 1916." Psychiatric Bull., vol. ii, 6–10 (Apr. 1917).
———. On utilizing the facts of juvenile promise and family history in awarding naval commissions to untried men. Proc. Nat. Acad. Sci., vol. 3, 404–409 (June 1917).
———. Inheritance of stature. Genetics, vol. ii, 313–389 (July 1917).
———. Heredity of stature. [Abstract] Proc. xix Internat. Congress of Americanists (1916).
———. Brief studies in heredity (unsigned) in Eugenical News, as follows: vol. i. C. E. Hughes, p.69; John Burroughs, p. 77; John Muir, p. 78; C. F. Adams, p. 85; and vol. ii, R. W. Gilder, p. 1; A. McL. Hamilton, p. 9; R. J. Campbell, p. 10; Horatio Nelson, p. 17; I. M. Wise, p.18; John Marshall, p. 25; J. W. Gerard, p. 26; G. F. Wright, p. 27; Charles Tupper, p. 33; Stonewall Jackson, p. 34; Martin Luther, p. 34; H. D. Thoreau, p. 41; Herbert Spencer, p. 42; W. H. Davies, p. 42; James Thomson, p. 43; Robert Hare, p. 49; J. M. Morgan, p. 50; J. J. Hill, p. 57; G. A. Grow, p. 58; Alfred Lyttelton, p. 65; P. Diaz, p. 72; F. Asbury, p.72.
———, and Elizabeth B. Muncey. Huntington's chorea in relation to heredity and eugenics. Amer. Jour. Insanity, vol. lxxiii, 195–222 (Oct. 1916); also Eugenics Record Office Bull. No. 17.
———. See Ritzman, E. G.
Davenport, Frances G. Materials for English diplomatic history, 1509–1783. 18th Rep. Royal Commission on Historical Manuscripts, Appendix ii, 357–402.
———. American and European diplomacy to 1648. Ann. Rep. Amer. Hist. Assoc., 151–161 (1915).
Davis, Edwin G. See Young, Hugh H.
Davis, Helen. See Shapley, Harlow.
Davis, H. S. See Richards, T. W.
Duesberg, J. Chondriosomes in fish embryos. Anat. Rec., vol. xi, 441 (1917).
———. Chondriosomes in the cells of fish embryos. Amer. Jour. Anat., vol. xxi, 465–498, 8 figs. (1917).
Dunn, L. C. The genetic behavior of mice of the color varieties, "black and tan" and "red." Amer. Nat., vol. l, 664–675 (Nov. 1916).
———. Nucleus and cytoplasm as vehicles of heredity. Amer. Nat., vol. li, 286–300 (May 1917).
Ellerman, Ferdinand. See Seares, Frederick H.
Ellis, J. H. See Burdick, C. L.
Evans, H. M., and G. W. Bartelmez. A human embryo of seven to eight somites. Anat. Rec., vol. xi, 355 (1917).
Fenner, C. N. See Morey, George W.
Ferguson, John B. The equilibrium between carbon monoxide, carbon dioxide, sulfur dioxide and free sulfur. Proc. Nat. Acad. Sci., vol. 3, 371–374 (1917).
———. The iodometric determination of sulfur dioxide and the sulfites. Jour. Amer. Chem. Soc., vol. xxxix, 364–373 (1917).
———. The determination of iron in glass sand. Jour. Ind. Eng. Chem., vol. 9, 941–943 (1917).
Fisher, Homer G., and Henry R. Muller. Unilateral destruction of the semicircular canals in cats. Amer. Jour. Physiol., vol. xli, 267–274 (1916).
Fleming, J. A. See Bauer, L. A.
Flotow, Albrecht von. The parallax problem in its application to the real motions of the fixed stars. Astron. Jour., No. 707 (Jan. 1917).
Franz, Shepherd Ivory. Cerebral adaptation vs. cerebral organology. Psychol. Bull., vol. 14, 137–140 (1917).
Free, E. E. Note on the swelling of gelatine and agar gels in solutions of sucrose and dextrose. Science, n. s., vol. xlvi, 142 (1917).
Gibson, K. S. The effect of temperature upon the coefficient of absorption of certain glasses of known composition. Phys. Rev., No. 2, vol. vii, 1914 (1916).

GIBSON, K. S. The effect of temperature upon the absorption spectrum of a synthetic ruby. Phys. Rev., No. 2, vol. VIII, 38, 1916.

GOLDFARB, A. J. Variability of germ-cells of sea-urchins. Proc. Nat. Acad. Sci., vol. 3, 241–245 (Apr. 1917).

GOODPASTURE, E. W., and GEORGE B. WISLOCKI. Old age in relation to cell-overgrowth and cancer. Johns Hopkins Hosp. Reports, vol. XVIII (1916); Jour. Med. Research, vol. XXXIII, 455–473 (1915–1916).

GORTNER, R. See HARRIS, J. ARTHUR.

HALE, GEORGE E. The intellectual inspiration of Paris. Science and Learning in France, 5–17 (1917).

———. How men of science will help in our war. Scribner's Mag., vol. 61, 721 (1917).

———. The national value of scientific research. Read at the opening exercises of the Massachusetts Institute of Technology, October 1916; Technology Rev., vol. 18, 801 (1916).

———. National Research Council: Basis of organization and means of cooperation with state councils of defense. Jour. Franklin Inst., vol. 183, 759 (1917).

———. Report of the chairman of the National Research Council. Ann. Rep. Nat. Acad. Sci. (1916).

———. National Research Council: Preliminary report of the organizing committee. Proc. Nat. Acad. Sci., vol. 2, 507 (1916).

———. Research committees in educational institutions. Proc. Nat. Acad. Sci., vol. 3, 223 (1917).

———. The best service of astronomers in time of war. Read at 21st meeting, Amer. Astron. Soc. (1917).

HALL, N. F. See RICHARDS, T. W.

HARRIS, J. ARTHUR. Variation, correlation and inheritance of fertility in the mammals. Amer. Nat., vol. L, 626–636 (Oct. 1916).

———. A quantitative study of the factors influencing the weight of the bean seed: II. Correlation between number of pods per plant and seed weight. Bull. Torr. Bot. Club, vol. XLIII, 485–494, figs. 1–4 (Sept. 1916).

———. Statistical studies of the number of nipples in the mammals. Amer. Nat., vol. L, 696–704 (Nov. 1916).

———. The application of correlation formulæ to the problem of varietal differences in disease resistance: Data from the Vermont experiments with potatoes. Amer. Nat., vol. LI, 238–244 (Apr. 1917).

———. Studies on the correlation between morphological and physiological characters: II. Further studies on the relationship between bilateral asymmetry and fertility and fecundity in the uniocular fruit. Genetics, vol. II, 186–204, figs. 1–3 (Mar. 1917).

———. Studies on the correlation between morphological and physiological characters: III. On the applicability of Pearson's bi-serial r to the problem of asymmetry and fertility in the uniocular fruit. Genetics, vol. II, 205–212, fig. 1 (Mar. 1917).

———. Studies on the correlation between morphological and physiological characters: IV. Supplementary determinations of the relationship between the number of ovules per pod and fertility in *Phaseolus*. Genetics, vol. II, 282–290, figs. 1–2 (May 1917).

———. Physical chemistry in the service of phytogeography. Science, n. s., vol. XLVI, 25–30 (July 1917).

———. Biometric studies on the somatic and genetic physiology of the sugar beet. Amer. Nat., vol. LI, 507–512 (Aug. 1917).

———, and JOHN V. LAWRENCE. On the osmotic pressure of the tissue fluids of Jamaican Loranthaceæ parasitic on various hosts. Amer. Jour. Bot., vol. III, 438–455, diags. 1–2 (Oct. 1916).

———, ———. The osmotic concentration of the sap of the leaves of mangrove trees. Biol. Bull., vol. XXXII, 202–211 (Mar. 1917).

———, ———. The osmotic concentration of the tissue fluids of Jamaican montane rain forest vegetation. Amer. Jour. Bot., vol. IV, 268–298 (May 1917).

———, A. F. BLAKESLEE, and C. D. WARNER. Body pigmentation and egg production in the fowl. Proc. Nat. Acad. Sci., vol. III, 237–241, figs. 1–3 (Apr. 1917).

———, ———, and D. E. WARNER, with the cooperation of W. F. KIRKPATRICK. The correlation between body pigmentation and egg production in the domestic fowl. Genetics, vol. II, 36–77, diags. 1–16 (Jan. 1917).

———, ———, and W. F. KIRKPATRICK. Inter-periodic correlation in the egg production of the domestic fowl. Proc. Nat. Acad. Sci., vol. 3, 565–569, figs. 1–2 (Sept. 1917).

———, R. A. GORTNER, and JOHN V. LAWRENCE. The relationship between the osmotic concentration of leaf sap and height of leaf insertion in trees. Bull. Torr. Bot. Club, vol. XLIV, 267–286, diags. 1–4 (June 1917).

———, and W. POPENOE. Freezing-point lowering of the leaf sap of the horticultural type of *Persea americana*. Jour. Agric. Res., vol. VII, 261–268 (Nov. 1916).

HARVEY, ETHEL BROWNE. A physiological study of *Noctiluca*, with special reference to light production, anæsthesia, and specific gravity. Proc. Nat. Acad. Sci., vol. 3, 15–16 (Jan. 1917).

Hatai, S. On the composition of the medusa, *Cassiopea xamachana*, and the changes in it after starvation. Proc. Nat. Acad. Sci., vol. 3, 22–24 (Jan. 1917).

Hay, Oliver P. Descriptions of some fossil vertebrates found in Texas. Bull. Univ. Texas, No. 71, 1–24, pls. 1–4 (1916).

———. On a collection of fossil vertebrates made by Dr. F. W. Cragin in the Equus beds of Kansas. Kans. Univ. Sci. Bull., vol. 10, 39–51, plates 1–3 (1916).

———. The Quaternary deposits at Vero, Florida, and the vertebrate remains contained therein. Jour. Geology, vol. 25, 52–55 (Jan. 1, 1917).

———. On the finding of supposed human remains at Vero, Florida. Jour. Wash. Acad. Sci., vol. 7, 358–359 (June 4, 1917).

———. Description of a new species of mastodon, *Gomphotherium elegans*, from the Pleistocene of Kansas. Proc. U. S. Nat. Mus., vol. 53, 219–221, plate 26 (June 1, 1917).

———. Description of a new species of extinct horse, *Equus lambei*, from the Pleistocene of Yukon Territory. Proc. U. S. Nat. Mus., vol. 53, 435–443, pls. 56–58 (June 5, 1917).

Higgins, Harold L. Effect of alcohol on the respiration and the gaseous metabolism in man. Jour. Pharmacol. and Exp. Therapeutics, vol. ix, 441 (1917).

Holtsmark, J. See Sverdrup, H. U.

Hostetter, J. C. See Sosman, R. B.; Wright, F. E.

Howes, H. L. On certain absorption bands in the spectra of the uranyl salts. Phys. Rev., No. 2, vol. x (1917).

———, and D. T. Wilber. The fluorescing sodium uranyl phosphate. Phys. Rev., No. 2, vol. vii, 394 (1916).

———, ———. The fluorescence of four double nitrates. Phys. Rev., No. 2, vol. x, 248 (1917).

———. See Nichols, E. L.

Hulburt, E. O., J. F. Hutchinson, and H. C. Jones. The absorption coefficient of solutions of cobalt chloride in water and various alcohols for monochromatic radiation. Jour. Phys. Chem. (Feb. 1917).

Hutchinson, J. F. See Hulburt, E. O.

Jameson, J. Franklin. Historical scholars in war-time. Amer. Hist. Rev., vol. xxii, 831–835.

Johnston, John. Some aspects of recent high-pressure investigation. Jour. Franklin Inst., vol. 183, 1–32 (1917).

Jones, H. C. See Hulburt, E. O.

Jordan, H. E. Aortic cell-clusters in vertebrate embryos. Proc. Nat. Acad. Sci., vol. 3, 149–156 (Mar. 1917).

———. The history of the primordial germ-cells in the loggerhead turtle. Proc. Nat. Acad. Sci., vol. 3, 271–277 (Apr. 1917).

Kempf, E. J. Two methods of subjective learning in the monkey *Macacus rhesus*. Jour. Animal Behav., vol. 6, 256–265 (1916).

———. Did consciousness of self play a part in the behavior of this monkey? Jour. Phil., Psychol., etc., vol. 13, 410–412 (1916).

King, Arthur S. A study with the electric furnace of the anomalous dispersion of metallic vapors. Astrophys. Jour., vol. 45, 254–268 (1917); Mt. Wilson Contr., No. 130.

———. The relation of laboratory investigation to astrophysical research. Pubs. A. S. P., vol. 29, 14 (1917).

———. The effect of oxygen on the production of band and line spectra in the electric furnace. Read at New York meeting, Amer. Phys. Soc. and A. A. A. S. (1916); [Abstract] Phys. Rev., ser. 2, vol. 9, 346 (1917).

———. Experiments with the electric furnace on the anomalous dispersion of metallic vapors. Read at New York meeting, Amer. Phys. Soc. and A. A. A. S. (1916); [Abstract] Phys. Rev., ser. 2, vol. 9, 347 (1917).

———. Leading features of the electric furnace spectra of calcium, strontium, barium, and magnesium. Read at Stanford meeting, Amer. Phys. Soc. (1917); [Abstract] Phys. Rev., ser. 2, vol. 9, 576 (1917).

———, and Edna Carter. Preliminary observations of the spectra of calcium and iron when produced by cathodo-luminescence. Astrophys. Jour., vol. xliv, 303–310 (1916); Mt. Wilson Contr., No 125.

———, ———. Experiments on the production of metallic spectra by cathodo-luminescence. Read at Cleveland meeting, Amer. Phys. Soc. (1916); [Abstract] Phys. Rev., ser. 2, vol. 9, 94 (1917).

King, R. W. The electrical conductivity of sputtered films. Phys. Rev., No. 2, vol. x, 291 (1917).

Kirkpatrick, W. F. See Harris, J. Arthur.

Knoche, W., and J. Laub. Meteorologische und luftelektrische Messungen während der totalen Sonnenfinsternis am 10 Oktober 1912 auf der Facenda Boã Vista bei Christina (Prov. Minas Geraes-Brasilien): II. Luftelektrische Beobachtungen. Terr. Mag., vol. 21, No. 4, 177–204 (Dec. 1916).

Koch, John C. The laws of bone architecture. Anat. Rec., vol. xi, 383 (1917); Amer. Jour. Anat., vol. xxi, 177–298, 28 figs., 5 pls. (1917).

LASHLEY, K. S. Modifiability of the preferential use of the hands in the Rhesus monkey. Jour. Animal Behav., vol. 7, 178–186 (1917).
LAUB, J. See KNOCHE, W.
LAWRENCE, JOHN V. See HARRIS, J. ARTHUR; RIDDLE, OSCAR.
LEAVENWORTH, CHARLES. See OSBORNE, THOMAS B.
LELAND, W. G. Concerning Catholic historical societies. Catholic Hist. Rev., vol. II, 386–399.
LIVINGSTON, B. E., and EDITH B. SHREVE. Improvements in the method for determining the transpiring power of plant surfaces by hygrometric paper. Plant World, vol. 19, No. 10 (1916).
LLOYD, F. E. Critical flowering and fruiting temperatures for *Phytolacca decandra*. Plant World, vol. 20, 121–126 (Apr. 1917).
———. The analogy between the behavior of gelatine and that of protoplasm. Trans. Roy. Soc. Can. (1917).
LOMBARD, ROBERT H. See ALLEN, E. T.
LONG, E. R. Further results in Echinocactus desiccation and respiration. Bot. Gaz., vol. 64 (1917).
LONGLEY, W. H. Observations upon tropical fishes and inferences from their adaptive coloration. Proc. Nat. Acad. Sci., vol. 2, 733–737 (Dec. 1916).
———. The selection problem. Amer. Nat., vol. LI, 250–256 (Apr. 1917).
———. Studies upon the biological significance of animal coloration: I. The color and color changes of West Indian Reef fishes. Jour. Exper. Zool., vol. 23, 536–601 (Aug. 1917).
———. Studies upon the biological significance of animal coloration: II. A revised working hypothesis of mimicry. Amer. Nat., vol. LI, 257–285 (May 1917).
MACDOUGAL, D. T. The beginning and physical basis of parasitism. Plant World, vol. 20, 238 (Aug. 1917).
———. A decade of the Salton Sea. Geog. Rev., vol. III, No. 6 (June 1917).
———. To increase the yield of food. North Amer. Rev., 62–69 (July 1917).
———, and H. A. SPOEHR. The measurement of light in some of its more important physiological aspects. Science, n. s., vol. XLV, No. 1172, 616–618 (June 15, 1917).
———, ———. The effect of acids and salts on biocolloids. Science, n. s., No. 1185, vol. XLV, 269–272 (Sept. 14, 1917).
———, ———. Growth and imbibition. Proc. Amer. Phil. Soc., vol. LVI, 289–352 (1917).
———, ———. The behavior of certain gels useful in the interpretation of the action of plants. Science, n. s., vol. XLV, No. 1168, 484–488 (May 18, 1917).
MACDOWELL, E. C. Piebald rats and multiple factors. Amer. Nat., vol. L, 719–742 (Dec. 1916).
———. Bristle inheritance in *Drosophila:* II. Selection. Jour. Exp. Zool., vol. 23, 109–146 (May 1917).
———. The bearing of selection experiments with *Drosophila* upon the frequency of germinal changes. Proc. Nat. Acad. Sci., vol. 3, 291–297 (Apr. 1917).
———, and E. M. VICARI. The influence of alcohol on the growth and fecundity of white rats. Proc. Acad. Sci., vol. 3, 577–579 (Sept. 1917).
MACKLIN, C. C. Notes on the preparation of bones from madder-fed animals. Anat. Rec., vol. XII, 403 (1917).
———. Observations on the effect of madder-feeding, especially with regard to deposits of calcium salts. Anat. Rec., vol. XI, 387 (1917).
———. Amitosis in cells growing in vitro. Biol. Bul., vol. XXX, 445–467 (1916).
———. See SHIPLEY, P. G.
MALL, FRANKLIN P. Organization and scope of the Department of Embryology. Circular No. 19 (1916). (Printed privately.)
———. Note on abortions with letters from the Health Commissioner of Baltimore and from the chief of the bureau of vital statistics of Maryland regarding the registration and shipment of embryos to the Carnegie Laboratory of Embryology at the Johns Hopkins Medical School. Circular No. 20 (1917). (Printed privately.)
———. The embryological collection of the Carnegie Institution. Circular No. 18 (1916). (Printed privately.)
MAUCHLY, S. J. See SWANN, W. F. G.
MAYER, A. G. Coral reefs of Tutuila, with reference to the Murray-Agassiz solution theory. Proc. Nat. Acad. Sci., vol. 3, 523–526 (Aug. 1917).
———. Further studies of nerve-conduction in *Cassiopea*. Amer. Jour. Physiol., vol. 42, 469–475 (1917).
———. On the non-existence of nervous shell-shock in fishes and marine invertebrates. Proc. Nat. Acad. Sci., vol. 3, 597–598.
MCCLENDON, J. F. The composition, especially the hydrogen-ion concentration of sea-water in relation to marine organisms. Jour. Biol. Chem., vol. 28, 135–152 (Dec. 1916).
MELDRUM, W. B. See RICHARDS, T. W.
MENDEL, LAFAYETTE B. See OSBORNE, THOMAS B.
MERRITT, ERNEST. See NICHOLS, E. L.
MERWIN, H. E. A table for linear and certain other interpolations on spectrograms. Amer. Jour. Sci., No. 4, vol. XLIII, 49–56 (1917).

MERWIN, H. E. Dispersion and other optical properties of carborundum. Jour. Wash. Acad. Sci., vol. 7, 445–447 (1917).

———. Optical properties and theory of color of pigments and paints. Proc. Amer. Soc. Testing Materials, 17, 494–526 (1917).

———. The setting of litharge-glycerine cement. Jour. Ind. Eng. Chem., vol. 9, 390 (1917).

METZ, C. W. Chromosome studies on the Diptera: III. Additional types of chromosome groups in the Drosophilidæ. Amer. Nat., vol. L, 587–599, 20 figs. (Oct. 1916).

———. Mutations in three species of *Drosophila*. Genetics, vol. 1, 591–607 (Nov. 1916).

MILES, W. R. Some psycho-physiological processes as affected by alcohol. Proc. Nat. Acad. Sci., vol. 2, 703 (1916).

MOREY, GEORGE W. A convenient form of autoclave. Jour. Wash. Acad. Sci., vol. 7, 205–208 (1917).

———, and C. N. FENNER. The ternary system H_2O–K_2SiO_3–SiO_2. Chemical study by George W. Morey, and microscopic study by C. N. Fenner. Jour. Amer. Chem. Soc., vol. XXXIX, 1173–1229 (1917).

MORGAN, T. H. A critique of the theory of evolution. Princeton Univ. Press (1916).

———. Goodale's experiments on gonadectomy of fowls. Science, n. s., vol. XLV, 483–484 (May 1917).

———. The theory of the gene. Amer. Nat., vol. LI (Sept. 1917).

———. An examination of the so-called process of contamination of genes. Anat. Rec., vol. XI, 503 (1917).

MULLER, HENRY R. See FISHER, HOMER G.

MUNCEY, ELIZABETH B. See DAVENPORT, C. B.

NICHOLS, E. L. Note on the phosphorescence of uranyl salts. Proc. Nat. Acad. Sci., vol. 2, 328 (1916).

———. Spectral structure of the phosphorescence of certain sulphides. Proc. Amer. Philos. Soc., vol. LVI, 258 (1917).

———, and H. L. HOWES. The fluorescence and absorption of certain pleochroic crystals of the uranyl salts. Phys. Rev., No. 2, vol. VIII, 364 (1916).

———, ———. On the phosphorescence of the uranyl salts. Phys. Rev., No. 2, vol. IX, 292 (1917).

———, ———. A synchrono-phosphoroscope. Phys. Rev., No. 2, vol. VII, 586 (1916); an article in extenso in Science, n. s., vol. XLIII, 937 (1916).

———, ———. A new phosphoroscope. Science, n. s., vol. XLIII, 937 (1916).

———, and E. MERRITT. Influence of water of crystallization upon the fluorescence and absorption spectra of uranyl nitrate. Phys. Rev., No. 2, vol. IX, 113 (1917).

———, and others. New data on the phosphorescence of certain sulphides. Proc. Nat. Acad. Sci., vol. 3, 199–202 (1917); pub. in extenso in Amer. Phil. Soc. Proc.

NICHOLSON, NORMAN CLIVE. Morphological and microchemical variations in mitochondria in the nerve-cells of the central nervous system. Amer. Jour. Anat., vol. XX, 329–349 (1916).

NICHOLSON, SETH B. The ninth satellite of Jupiter. Proc. Nat. Acad. Sci., vol. 3, 147–149 (1917); Mt. Wilson Communications, No. 41.

———, and HARLOW SHAPLEY. The photographic magnitude of the ninth satellite of Jupiter. Pubs. A. S. P., vol. 28, 281 (1916).

———, ———. Observations of the ninth satellite of Jupiter. Astron. Jour., vol. 30, 129 (1917).

———, ———. The orbit and probable size of a very faint asteroid. Astron. Jour., vol. 30, 127 (1917).

OSBORNE, THOMAS B., and CHARLES LEAVENWORTH. Protein copper compounds. Jour. Biol. Chem. (Dec. 1916).

———, and LAFAYETTE B. MENDEL. The rôle of vitamines in the diet. Jour. Biol. Chem. (July 1917).

———, ———. The incidence of phosphatic urinary calculi in rats fed on experimental rations. Jour. Amer. Med. Assoc. (July 7, 1917).

———, ———. The use of cotton seed as food. Jour. Biol. Chem. (Mar. 1917); Proc. Amer. Physiol. Soc.; Amer. Jour. Physiol. (1917).

———, ———. The relative value of certain proteins and protein concentration as supplements to corn gluten. Jour. Biol. Chem. (Feb. 1917).

———, ———. The growth of rats upon diets of isolated food substances. Biochem. Jour. (Dec. 1916).

———, ———. The effect of the amino-acid content of the diet on the growth of chickens. Jour. Biol. Chem. (Sept. 1916).

———, ———. The effect of retardation of growth upon the breeding period and duration of life of rats. Science, n. s., No. 1160, vol. XLV, 294–295 (Mar. 23, 1917).

———, and ALFRED J. WAKEMAN. Some new constituents of milk: Second Paper. The distribution of phosphatides in milk. Jour. Biol. Chem. (Dec. 1916).

PEASE, FRANCIS G. Hind's variable nebula N. G. C. 1555. Astrophys. Jour., vol. 45, 89 (1917); Mt. Wilson Contr., No. 127.

Pease, Francis G., Photographs of nebulæ with the 60-inch reflector 1911–1916. Astrophys. Jour., vol. xlvi, No. 24–55 (1917); Mt. Wilson Contr., No. 132.
———. Mt. Wilson's 100-inch reflector. Sci. Amer., vol. 117, 100 (Aug. 11, 1917).
———, and Harlow Shapley. On the distribution of stars in twelve globular clusters. Astrophys. Jour., vol. 45, 225–243 (1917); Mt. Wilson Contr., No. 129.
———, ———. Axes of symmetry in globular clusters. Proc. Nat. Acad. Sci., vol. 3, 96–101 (1917); Mt. Wilson Communications, No. 39.
———, ———. Note on the elliptical form of Messier 13. Read at 20th meeting, Amer. Astron. Soc. (1916); [Abstract] Pop. Astron., vol. 25, 374 (1917).
Peters, W. J. See Bauer, L. A.
Popenoe, W. See Harris, J. Arthur.
Pratt, H. S. Trematodes of the loggerhead turtle (*Caretta caretta*) of the Gulf of Mexico. Archives de Parisitologie, tome 16, 411–427, pls. 4, 5, 13 figs. (1914).
Richards, T. W. Atoms. Youth's Companion (Mar. 20, 1917).
———, and H. S. Davis. Improvements in calorimetric combustion, and the heat of combustion of toluene. Proc. Nat. Acad. Sci., vol. 3, 50 (Jan. 1917); Jour. Amer. Chem. Soc., vol. xxxix, 341 (Mar. 1917).
———, and N. F. Hall. Attempt to separate the isotopic forms of lead by fractional crystallization. Jour. Amer. Chem. Soc., vol. xxxix, 531 (Apr. 1917); Proc. Nat. Acad. Sci., vol. 3, 339 (May 1917).
———, and W. B. Meldrum. The melting points of the chlorides of lithium, rubidium, and cæsium, and the freezing points of binary and ternary mixtures of these salts, including also potassium and sodium chloride. Jour. Amer. Chem. Soc., vol. xxxix, 1816 (Sept. 1917).
———, and H. W. Richter. On the absence of thermal hysteresis in the copper-constantan thermoelement between 30° and 100° C. Jour. Amer. Chem. Soc., vol. xxxix, 231 (Feb. 1917).
———, and C. Wadsworth, 3d. Further study of the atomic weight of lead of radio-active origin. Jour. Amer. Chem. Soc., vol. xxxviii, 2613 (Dec. 1916); Proc. Nat. Acad. Sci., vol. 2, 694 (Dec. 1916).
Richter, H. W. See Richard, T. W.
Riddle, Oscar. Size and length relations of the right and left testes of pigeons in health and disease. Anat. Rec., vol. xi, 87–102 (Oct. 1916).
———. The control of the sex ratio. Jour. Wash. Acad. Sci., vol. vii, 319–356 (June 4, 1917).
———. The theory of sex as stated in terms of results of studies on pigeons. Science, n. s., vol. xlvi, 19–24 (July 6, 1917).
———, and J. V. Lawrence. Studies on the physiology of reproduction in birds: VII. Variations in the chemical composition of reproductive tissues in relation to functional activity. Amer. Jour. Physiol., vol. xlii, 151–162 (Dec. 1916).
Ritzman, E. G., and C. B. Davenport. Family performances as a basis for selections in sheep. Jour. Agri. Research, vol. x, 93–97 (July 1917).
Sabin, Florence R. The method of growth of the lymphatic system. The Harvey Lectures, series xi, 124–145 (1915–1916).
———. The method of growth of the lymphatic system. Science, n. s., vol. xliv, 145–158 (1916).
Schultz, Adolf H. Ein paariger Knocken am Unterrand der Squama occipitalis. Anat. Rec., vol. xii, 357–362, 2 figs. (1917).
Scott, W. J. M. Experimental mitochondrial changes in the pancreas in phosphorous poisoning. Amer. Anat., vol. xx, 237–251, 1 pl., 7 figs. (1916).
Seares, Frederick H. A determination of the galactic condensation from certain zones of the Astrographic Catalogue. Astrophys. Jour., vol. 46, 117–137 (1917); Mt. Wilson Contr., No. 135.
———. The color of the standard polar stars determined by the method of exposure-ratios. Proc. Nat. Acad. Sci., vol. 3, 29 (1917); Mt. Wilson Communications, No. 38.
———. Photographic magnitudes of stars in the Selected Areas of Kapteyn. Proc. Nat. Acad. Sci., vol. 3, 188–191 (1917); Mt. Wilson Communications, No. 42.
———. Preliminary note on the distribution of stars with respect to the galactic plane. Proc. Nat. Acad. Sci., vol. 3, 217–222 (1917); Mt. Wilson Communications, No. 43.
———. Further evidence on the concentration of the stars toward the galaxy. Proc. Nat. Acad Sci., vol. 3, 558–562 (1917); Mt. Wilson Communications, No. 49.
———. Magnitudes and color of Barnard's proper-motion star, $17^h53^m44^s$ $+4°27'.8$ (1916). Pubs. A. S. P., vol. 28, 280 (1916).
———. The Mount Wilson Solar Observatory. Pubs. A. S. P., vol. 29, 155 (1917).
———, Adriaan van Maanen, and Ferdinand Ellerman. The location of the sun's magnetic axis. Read at 21st meeting, Amer. Astron. Soc. (1917).
Shapley, Harlow. Studies based on the colors and magnitudes in stellar clusters. [Abstract of Mt. Wilson Contr., Nos. 115, 116, and 117.] Astrophys. Jour., vol. 45, 118 (1917).

Shapley, Harlow. Studies based on the colors and magnitudes in stellar clusters: Fourth paper. The galactic cluster Messier 11. Astrophys. Jour., vol. 45, 164 (1917); Mt. Wilson Contr., No. 126.

———. Studies based on the colors and magnitudes in stellar clusters: Fifth paper. Color-indices of stars in the galactic clouds. Astrophys. Jour., vol. 46, 64–75, (1917); Mt. Wilson Contr., No. 133.

———. The variations in spectral type of twenty Cepheid variables. Astrophys. Jour., vol. 44, 273–291 (1916); Mt. Wilson Contr., No. 124.

———. Studies of the magnitudes in star clusters: IV. On the color of stars in the galactic clouds surrounding Messier 11. Proc. Nat. Acad. Sci., vol. 3, 25 (1917); Mt. Wilson Communications, No. 37.

———. Studies of the magnitudes in star clusters: V. Further evidence of the absence of scattering of light in space. Proc. Nat. Acad. Sci., vol. 3, 267 (1917); Mt. Wilson Communications, No. 44.

———. Studies of the magnitudes in star clusters: VI. The relation of blue stars and variables to galactic planes. Proc. Nat. Acad. Sci., vol. 3, 276 (1917); Mt. Wilson Communications, No. 45.

———. Studies of the magnitudes in star clusters: VII. A method for the determination of the relative distances of globular clusters. Proc. Nat. Acad. Sci., vol. 3, 479 (1917); Mt. Wilson Communications, No. 47.

———. On the distribution of stars in globular clusters. Observatory, vol. 39, 452 (1916).

———. A new variable star. Pubs. A. S. P., vol. 28, 282 (1916).

———. Light elements of variable No. 37 in Messier 3. Pubs. A. S. P., vol. 29, 110 (1917).

———. Hypothetical parallaxes of 36 stars. Pubs. A. S. P., vol. 29, 139 (1917).

———. A distant star in high galactic latitude. Pubs. A. S. P., vol. 29, 183 (1917).

———. Descriptive notes relative to nine clusters. Pubs. A. S. P., vol. 29, 185 (1917).

———. Notes on stellar clusters. Read at 20th meeting, Amer. Astron. Soc. (1916); [Abstract] Pop. Astron., vol. 25, 379 (1917).

———, and Helen Davis. Messier's catalog of nebulæ and clusters. Pubs. A. S. P., vol. 29, 177 (1917).

———. On the variations in the periods of variable stars in Messier 3. Pubs. A. S. P., vol. 29, 140 (1917).

———. See Nicholson, Seth B.; Pease, Francis G.

Shapley, Martha Betz. The color-curve of XZ Cygni. Astrophys. Jour., vol. 45, 182–188 (1917); Mt. Wilson Contr., No. 128.

———. The period of U Cephei. Astrophys. Jour., vol. 44, 51 (1916).

———. Light-curves and orbital elements of TT Lyræ and Y Camelopardalis. Astrophys. Jour., vol. 46, 56 (1917).

Shipley, P. G., and R. S. Cunningham. The histology of blood and lymphatic vessels during the passage of foreign fluids through their walls. Anat. Rec., vol. xi, 181 (1916).

———, and C. C. Macklin. The demonstration of centers of osteoblastic activity by use of vital dyes of the benzidene series. Anat. Rec., vol. x, 597–599 (1916).

———, ———. Some features of osteogenesis in the light of vital staining. Amer. Jour. Physiol., vol. xlii, 117–123 (1916–1917).

Shreve, Edith B. See Livingston, B. E.

Shreve, Forrest. The weight of physical factors in the study of plant distribution. Plant World, vol. 19, 53–67 (1916).

———. Excursion impressions. Trans. San Diego Soc. Nat. Hist., vol. 2, 79–83 (1916).

———. A map of the vegetation of the United States. Geog. Rev., vol. 3, 119–125, with map (1917).

———. The physical control of vegetation in rain-forest and desert mountains. Plant World, vol. 20, 135–141 (1917).

———. The density of stand and rate of growth of Arizona yellow pine as influenced by climatic conditions. Jour. Forestry, vol. 15, 695–707 (Oct. 1917).

Sosman, Robert B. Some problems of the oxides of iron. Jour. Wash. Acad. Sci., vol. 7, 55–72 (1917).

———, and J. C. Hostetter. The ferrous iron content and magnetic susceptibility of some artificial and natural oxides of iron. Bull. Amer. Inst. Mining Eng., 907–931 (1917).

———, ———. Zonal growth in hematite, and its bearing on the origin of certain iron ores. Bull. Amer. Inst. Mining Eng., 933–943 (1917).

Spoehr, H. A. See MacDougal, D. T.

St. John, Charles E. Observational evidence that the relative positions of Fraunhofer lines are not systematically affected by anomalous dispersion. Astrophys. Jour., vol. 44, 311 (1916); Mt. Wilson Contr., No. 123.

———. The principle of generalized relativity and the displacement of Fraunhofer lines toward the red. Astrophys. Jour., vol. 46; Mt. Wilson Contr., No. 138.

———. A search for an Einstein relativity-gravitational effect in the sun. Proc. Nat. Acad. Sci., vol. 3, 450 (1917); Mt. Wilson Communications, No. 46.

St. John, Charles E. Anomalous dispersion in the sun. Observatory, vol. 39, 462 (1916).
———, and Walter S. Adams. The question of diffused light in Mount Wilson solar observations. Jour. R. A. S. Canada, vol. 10, 553 (1916).
———, and Harold D. Babcock. The elimination of pole effect from the source for secondary standards of wave-length. Astrophys. Jour., vol. 46, 138-166 (1917); Mt. Wilson Contr., No. 137.
———, ———. The development of a source for standard wave-lengths and the importance of their fundamental values. Proc. Nat. Acad. Sci., vol. 3, 505 (1917); Mt. Wilson Communications, No. 48.
———. See Babcock, Harold D.
Störmer, Carl. Photographs of the Aurora Borealis. Astrophys. Jour., vol. 45, 67 (1917).
Streeter, George L. Histogenesis of the otic capsule. Anat. Rec., vol. xi, 417 (1917).
———. The development of the scala tympani, scala vestibuli and perioticular cistern in the human embryo. Amer. Jour. Anat., vol. xxi, 299-320, 9 figs. (1917).
Stromberg, Gustaf, See Adams, Walter.
Strongman, B. Talbot. A preliminary experimental study on the relation between mitochondria and discharge of nervous activity. Anat. Rec., vol. xii, 167–171 (1917).
Sturtevant, A. H. Notes on the North American Drosophilidæ, with description of twenty-three new species. Annals Entomol. Soc. Amer., vol. 9, 323 (Dec. 1916).
———. An analysis of the effect of selection on bristle number in a mutant race of Drosophila. Anat. Rec., vol. xi, 504 (Jan. 1917).
———. Crossing over without chiasmatype? Genetics, vol. 2, No. 3 (May 1917).
Sverdrup, H. U. Ueber den Energieverbrauch der Atmosphäre. Veröffentlichüngen des Geophysikal. Instituts der Universität Leipzig, ii Serie, Band ii, Heft 4.
———. Zur Bedeutüng der Isallobarenkarten. Annalen der Hydrographie und maritimen Meteorologie.
———. Ueber die Korrelation zwischen Vektoren mit Anwendüngen auf meteorologische Aufgaben. Meteorol. Zeitsch.
———. Zur Kenntniss des nordatlantischen Passates. Zeitschrift der Gesellschaft für Erdkünde.
———. Der nordatlantische Passat. Veröffentlichüngen des Geophysikal. Instituts der Universität Leipzig, ii serie, Band ii, Heft 1 (1917).
———, and J. Holtsmark. Ueber die Reibung an der Erdoberfläche und die direkte Vorausberechnung des Windes mit Hilfe der hydrodynamischen Bewegungsgleichüngen. Veröffentlichüngen des Geophysikal. Instituts der Universität Leipzig, ii Serie, Band ii, Heft 2.
———. Ueber die Beziehüng zwischen Beschleünigungen und Gradientenänderungen und ihre prognostische Verwendung. Veröffentlichüngen des Geophysikal. Instituts der Universität, Leipzig, ii Serie, Band ii, Heft. 3.
Swann, W. F. G. Equipartition of energy and radiation theory. Phil. Mag., vol. 33, No. 193 (Jan. 1917).
———. The origin of the Earth's charge. [Abstract] Jour. Wash. Acad. Sci., vol. 7, No. 9, 270–271 (May 4, 1917); Phys. Rev., ser. 2, vol. 9, No. 6, 555–557 (June 1917).
———. Note concerning the measurement of ionic density on the top of a tower. Terr. Mag., vol. 22, No. 3, 125–127 (Sept. 1917).
———. Gockel's recent atmospheric observations in Switzerland. [Abstract] Terr Mag., vol. 22, No. 3, 135–138 (Sept. 1917).
———, and S. J. Mauchly. On the conduction of electricity through an ionized gas, more particularly in its relation to Bronson resistances. Terr. Mag., vol. 22, No. 1, 1–21 (Mar. 1917).
———. See Bauer, L. A.
Talbot, Fritz B. Physiology of the new-born infant. Amer. Jour. Diseases of Children, vol. xiii, 495 (1917).
———. Twenty-four hour metabolism of two normal infants with special reference to the total energy requirements of infants. Amer. Jour. Diseases of Children, vol. xiv, 25 (1917).
van der Bilt, J. Transparency of the atmosphere at the Mount Wilson Solar Observatory. Pubs. A. S. P., vol. 29, 41 (1917).
van Maanen, Adriaan. The photographic determination of stellar parallaxes with the 60-inch reflector. Second series. Mt. Wilson Contr., No. 136.
———. The parallax of the planetary nebula N. G. C. 7662. Proc. Nat. Acad. Sci., vol. 3, 133-136 (1917); Mt. Wilson Communications, No. 40.
———. The parallaxes of B. D. +35°4001 and B. D. +35°4013. Pubs. A. S. P., vol. 28, 279 (1916).
———. Preliminary parallax of Messier 51 (N. G. C. 5194). Pubs. A. S. P., vol. 29, 182 (1917).
———. The 150-foot tower telescope of the Mount Wilson Solar Observatory. Jour. R. Astron. Soc. Canada, vol. 11, 223 (1917).
———. Discussion of the Mount Wilson parallaxes. Read at 21st meeting, Amer. Astron. Soc. (1917).
———. See Seares, Frederick H.

VICARI, E. M. See MACDOWELL, E. G.
WADSWORTH, C., 3D. See RICHARDS, T. W.
WAKEMAN, ALFRED J. See OSBORNE, THOMAS B.
WARNER, C. D. See HARRIS, J. ARTHUR.
WARNER, D. W. See HARRIS, J. ARTHUR.
WASHINGTON, HENRY S. Persistence of vents at Stromboli and its bearing on volcanic mechanism. Bull. Geol. Soc. Amer., vol. 28, 249–278 (1917).
WEED, LEWIS H. An anatomical consideration of the cerebro-spinal fluid. Anat. Rec., vol. XII, 461 (1917).
———. Progressive movements in decerebrate kittens. Anat. Rec., vol. XI, 429 (1917).
———. The reactions of kittens after decerebration. Amer. Jour. Physiol., vol. XLIII, 131–157 (1917).
WHEELER, THEODORA. Study of a human spina bifida monster with encephaloceles and other abnormalities. Anat. Rec., vol. XI, 431 (1917).
WILBER, D. T. See HOWES, H. L.
WILLIAMSON, ERSKINE, D. The effect of strain on heterogeneous equilibrium. Phys. Rev., n. s., vol. X, 275–283 (1917).
WISLOCKI, GEORGE B. A new method for the study of the development of the lymphatic system. Anat. Rec., vol. XI, 437 (1917).
———. The action of vital dyes in teleosts. Anat. Rec., vol. XII, 415 (1917).
———. The staining of amphibian larvæ with benzidine dyes of the lymphatic endothelium. Amer. Jour. Physiol., vol. XLII, 124–132 (1917).
———. See GOODPASTURE, E. W.
WRIGHT, F. E. The petrographic microscope, a useful tool in applied optics. Jour. Optical Soc. Amer., vol. 1, 15–21 (1917).
———. The crystallization of menthol. Jour. Amer. Chem. Soc., vol. XXXIX, 1515–1524 (1917).
———. Crystallographic and optic properties of mannoketoheptose and of the osazones of mannoketoheptose and mannoaldoheptose. Jour. Biol. Chem., vol. 28, 523–526 (1917).
———, and J. C. HOSTETTER. The thermodynamic reversibility of the equilibrium relations between a strained solid and its liquid. Jour. Wash. Acad. Sci., vol. 7, 405–417 (1917).
YOUNG, HUGH H., and EDWIN G. DAVIS. Double ureter and kidney with calculous pyronephrosis of one half. The embryology and surgery of double ureter and kidney. Jour. of Ureology, vol. I (1917).

REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the year 1916–1917.

During the fiscal year ending October 31, 1917, the Executive Committee held nine meetings. Printed reports of these meetings have been mailed to each Trustee of the Institution.

A vacancy in the Executive Committee, caused by the resignation of Mr. Welch, was filled by the election of Mr. Paton by the Board of Trustees at its meeting of December 15, 1916. Upon the adjournment of the Board the members of the Executive Committee met and organized by the election of Mr. Walcott as Chairman for 1917, and by voting that the Assistant Secretary of the Institution act as Secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1916–1917, together with itemized financial statements for the same period and a summary of receipts and expenditures of the Institution to date. The President also submits a report and an outline of suggested appropriations for the year 1917. The Executive Committee hereby approves the report and the recommendations of the President as the report and recommendations of the Committee.

The Board of Trustees at its meeting of December 15, 1916, instructed the Executive Committee to appoint Messrs. Arthur Young and Company, of Chicago and New York, to audit the accounts of the Institution for the fiscal year ending October 31, 1917. The report of this company, including their balance sheet showing the assets and liabilities of the Institution on October 31, 1917, is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

A vacancy in the Board of Trustees, occasioned by the resignation of Mr. Andrew D. White, calls for action at the coming meeting of

the Board of Trustees. In accordance with provision of the By-Laws, nominations to fill such vacancy have been requested and submitted to members of the Board.

The tenures of office of Mr. Henry White and of Mr. C. D. Walcott, as members of the Executive Committee, terminate at the coming annual meeting.

Charles D. Walcott, *Chairman.*
Cleveland H. Dodge.
Wm. Barclay Parsons.
Stewart Paton.
Henry S. Pritchett.
Elihu Root.
Henry White.
Robert S. Woodward.

November 19, 1917.

REPORT OF AUDITORS.

New York, *November 30, 1917.*

The Board of Trustees of the Carnegie Institution of Washington:

Dear Sirs: We have audited the books and records of the Carnegie Institution of Washington for the year ending October 31, 1917, and hereby certify that the statement of the receipts and disbursements for that period and the balance sheet at October 31, 1917, on pages 51–53 accurately reflect the transactions of the year and the financial condition of the Institution at the close of the year.

The investment securities of the endowment and other funds were examined by us and found to be in accordance with the lists on pages 54–56.

The cash on hand was verified by actual count and the balances in banks were confirmed with letters from the various depositaries.

The income from the investment securities has been accounted for and properly approved vouchers have been submitted to us for all payments made.

The accounts of the Departments of Research, which the Bursar of the Institution has audited for some years past under instructions from the Trustees, were not examined by us.

Yours very truly,

Arthur Young & Co.

Balance sheet, October 31, 1917.

ASSETS.

CAPITAL ASSETS:		
Endowment and other Fund Investments:		
Real estate, buildings and equipment at original cost (pp. 31–32).	$2,547,120.09	
Bonds and debentures (pages 54–55).	24,313,825.15	
		$26,860,945.24
Cash awaiting investment (page 52)		104,800.11
		26,965,745.35
CURRENT ASSETS:		
Inventories:		
Publications on hand, at sales prices.	263,472.80	
Paper stock	20,678.63	
	284,151.43	
Accounts receivable:		
Sundry debtors, for publications sold.	1,708.17	
	285,859.60	
Cash:		
In banks (page 52)	344,913.24	
Petty cash fund	300.00	
	345,213.24	
Income receivable as estimated for the calendar year 1917 (balance uncollected)	122,134.88	
	467,348.12	
		753,207.72
SPECIAL DEPOSITS		10,000.00
		27,728,953.07

CAPITAL AND LIABILITIES.

CAPITAL:		
Endowment funds:		
Carnegie endowment (page 56)	$22,120,000.00	
Colburn Fund (page 56)	85,414.33	
		$22,205,414.33
Reserve funds:		
General reserve fund (page 56)	2,010,743.74	
Insurance fund (page 56)	202,467.19	
		2,213,210.93
Income capitalized		2,547,120.09
		26,965,745.35
INCOME ACCOUNT, BALANCE:		753,207.72
NOTE.—Of the above balance there have been expended and appropriated the following sums:		
Expended for publications, etc., on hand	285,859.60	
Appropriated for:		
Large grants	170,738.23	
Minor grants	61,429.04	
Publications	80,443.77	
Administrative expenses	14,258.15	
	326,869.19	
Balance unappropriated	140,478.93	
	753,207.72	
NATIONAL RESEARCH COUNCIL		10,000.00
		27,728,953.07

Statement of cash receipts and disbursements for the year ending October 31, 1917.

RECEIPTS.

INTEREST FROM:		
Endowment:		
Bonds	$1,100,408.75	
Bank balance	8,164.43	
		$1,108,573.18
Reserve Fund:		
Bonds	78,680.00	
Bank balance	1,624.09	
		80,304.09
Insurance Fund:		
Bonds	7,942.11	
Bank balance	137.26	
		8,079.37
Colburn Fund:		
Bonds	4,065.00	
Bank balance	89.71	
		4,154.71
SALES OF PUBLICATIONS:		
Index Medicus	4,616.21	
Year Book	51.55	
Miscellaneous books	7,253.59	
		11,921.35
REFUNDS ON GRANTS		32,950.22
REDEMPTION OF SECURITIES:		
Buffalo City Gas Company		2,835.00
MISCELLANEOUS:		
Carnegie Corporation of New York	170,000.00	
Administration	922.50	
Unappropriated balance	3,391.21	
Sales of printing paper	2,463.26	
		176,776.97
		1,425,594.89
Balance October 30, 1916		444,582.61
		1,870,177.50

DISBURSEMENTS.

INVESTMENTS		$502,254.05
INSURANCE		3,219.44
GRANTS:		
Large	$695,813.07	
Minor	87,526.69	
		783,339.76
PUBLICATIONS		62,884.61
NATIONAL RESEARCH COUNCIL		10,000.00
ADMINISTRATION:		
Trustees' expenses	3,344.13	
Executive Committee	1,679.20	
Salaries	29,435.50	
Publications: Shipping expenses	4,765.40	
Surety, rent, telephone	431.86	
Equipment	144.33	
Postage, express, etc	457.01	
Printing, paper (including Year Book)	3,944.97	
Office supplies, petty expenses	1,291.39	
Building and grounds:		
Supplies and janitor service	2,251.89	
Fuel, light, water	1,020.61	
		48,766.29
		1,410,464.15
CASH IN BANKS:		
Uninvested principal:		
Endowment	777.45	
Reserve Fund	94,590.65	
Insurance Fund	4,312.68	
Colburn Fund	5,119.33	
	104,800.11	
Drawing accounts	344,913.24	
Special deposit	10,000.00	
		459,713.35
		1,870,177.50

Aggregate receipts and disbursements from Organization, January 28, 1902, to October 31, 1917.

RECEIPTS.

Interest:		
Endowment bonds	*$12,324,715.58	
Reserve Fund bonds	282,197.34	
Insurance Fund bonds	32,459.12	
Colburn Fund bonds	6,403.61	
		$12,645,775.65
Colburn Fund		52,015.74
Sales of Publications:		
Index Medicus	59,708.09	
Year Book	912.81	
Miscellaneous	67,808.64	
		128,429.54
Refund on Grants		69,666.42
Miscellaneous:		
Carnegie Corporation of New York	170,000.00	
Organization	1,825.52	
Sale of furniture	87.00	
Postage, express, travel	56.65	
Printing and paper	9,951.76	
Sale of metal and prints	3,195.83	
Sale of vessel	300.00	
Refund: Shipping	1,077.32	
Office	159.67	
Insurance	4,717.00	
Telephone, light	34.89	
Trustees	32.03	
Building	368.53	
Executive Committees	25.00	
Bond commission	1,274.37	
		193,105.57
Redemption and Sale of Bonds:		
U. S. Steel Corporation	920,000.00	
Northern Pacific-Great Northern	48,000.00	
Northern Pacific	102,750.00	
Atchison, Topeka & S. F.	49,500.00	
Lake Shore & Michigan Southern	47,000.00	
Central Pacific	48,250.00	
Baltimore & Ohio	26,000.00	
Cumberland Telephone Co	2,000.00	
Iowa Telephone Co	25,000.00	
Nebraska Telephone Co	13,000.00	
Cleveland Telephone Co	10,000.00	
New York City 6 per cent bonds	50,000.00	
Buffalo City Gas Co. bonds	2,835.00	
		1,344,335.00
		14,433,327.92

*Including interest from Income and Building Fund bonds.

DISBURSEMENTS.

Investment:		
Securities	$3,542,413.39	
Collection charges	2,763.48	
Administration building and site	309,915.69	
		$3,855,092.56
Insurance		3,270.94
Grants:		
Large	7,187,775.85	
Minor	1,578,531.24	
		8,766,307.09
Publications		644,017.62
National Research Council		10,000.00
Administration:		
Trustees' expenses	39,738.11	
Executive Committee	25,564.05	
Honorariums	17,319.81	
Salaries	411,645.53	
Publication: Shipping expenses	37,010.81	
Rent, surety, telephone	30,926.33	
Equipment	14,441.40	
Stationery	13,225.92	
Postage, express	21,282.64	
Printing	†42,968.57	
Office expenses	8,330.87	
Building and grounds:		
Supplies and janitor service	17,699.21	
Fuel, light, water	7,048.06	
Organization (1902)	1,825.52	
Plans and option	5,166.46	
Seal (1903)	555.60	
Miscellaneous	70.23	
		694,819.12
Refund:		
Publication	20.25	
Index Medicus	86.99	
		107.24
		13,973,614.57
Cash in Banks (page 52)		459,713.35
		14,433,327.92

†Including Year Books.

Schedule of Securities.

Par value.	Securities.	Investment value.	Total.
	ENDOWMENT.		
$21,200,000	U. S. Steel Corporation, registered 50-year 5 per cent gold bonds, Series A, B, C, D, E, F, due Apr. 1, 1951	$21,200,000.00	
175,000	Chicago, Milwaukee & Puget Sound Rwy. Co., first mortgage 4 per cent gold bonds, due Jan. 1, 1949	159,268.00	
14,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ per cent gold bonds, due May 1, 1989	13,953.75	
325,000	Lehigh & Lake Erie R. R. Co., first mortgage 4½ per cent 50-year gold bonds, due Mar. 1, 1957	331,568.30	
237,000	New York City 4½ per cent registered bonds, due Mar. 1, 1963.	253,557.50	
150,000	South & North Alabama R. R. Co., consolidated mortgage 5 per cent bonds, due Aug. 1, 1936	160,875.00	$22,119,222.55
	COLBURN FUND.		
20,000	Acker, Merrall and Condit Co., debenture 6 per cent bonds	13,600.00	
4,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ per cent bonds, due 1989	4,070.00	
8,000	Park and Tilford Co., sinking fund, debenture 6 per cent bonds.	6,400.00	
50,000	Pennsylvania R. R. Co., general mortgage 4½ per cent bonds, due June 1, 1965	51,925.00	
42,000	Pittsburgh, Shawmut & Northern R. R., first mortgage 4 per cent bonds, due Feb. 1, 1952	4,200.00	
	United States Government Second Liberty Loan of 1917 (2 per cent instalment)	100.00	80,295.00
	INSURANCE FUND.		
28,000	American Telephone & Telegraph Co., 4½ per cent convertible bonds	28,978.00	
50,000	Atchison, Topeka & Santa Fe Rwy. Co., general mortgage 100-year 4 per cent registered gold bonds, due 1995	50,056.25	
25,000	Bell Telephone Co. of Canada, debenture 5 per cent bonds, due Apr. 1, 1925	24,760.00	
30,000	Chicago, Burlington & Quincy R. R. Co., general mortgage 4 per cent bonds, due Mar. 1, 1958	28,237.50	
1,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ per cent gold bonds, due May 1, 1989	995.00	
21,000	Great Northern Rwy., first and refunding 4¼ per cent bonds, due 1961	20,944.00	
21,000	Illinois Central R. R. Co., refunding mortgage 4 per cent bonds, due Nov. 1, 1955	19,008.75	
24,000	Pennsylvania R. R. Co., consolidated mortgage, 4½ per cent bonds, due Aug. 1, 1960	25,095.01	
	United States Government Second Liberty Loan of 1917, (2 per cent instalment)	80.00	198,154.51
	RESERVE FUND.		
50,000	American Telephone & Telegraph Co., collateral trust 4 per cent bonds, due 1929	45,500.00	
96,000	American Telephone & Telegraph Co., 4½ per cent convertible bonds	99,456.25	
100,000	Baltimore & Ohio R. R. Co., general and refunding 5 per cent bonds, due 1995	102,375.00	
50,000	Central Pacific Rwy. Co., first refunding mortgage 4 per cent registered gold bonds, due 1949	48,250.00	
150,000	Chicago, Burlington & Quincy R. R. Co., general mortgage 4 per cent bonds, due Mar. 1, 1958	141,263.75	
15,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ per cent gold bonds, due May 1, 1989	14,925.00	
22,886,000	Carried forward	$451,770.00	22,397,672.06

Schedule of Securities.—Continued.

Par value.	Securities.	Investment value.	Total.
$22,886,000	Brought forward	$451,770.00	$22,397,672.06
120,000	Chicago and Northwestern general mortgage $3\frac{1}{2}$ per cent bonds, due Nov. 1, 1987	100,300.00	
155,000	General Electric, 5 per cent gold debenture bonds	158,213.47	
48,000	Great Northern Rwy. Co., first and refunding mortgage $4\frac{1}{4}$ per cent bonds, due 1961	48,109.25	
100,000	Illinois Central R. R. Co., refunding 4 per cent bonds, due 1955	89,668.75	
280,000	Interborough Rapid Transit Co., first refunding mortgage 5 per cent bonds, due 1966	276,701.00	
50,000	Lake Shore & Michigan Southern Rwy. Co., registered 25-year 4 per cent gold bonds, due Sept. 1, 1928	47,000.00	
50,000	Long Island Railroad Co., refunding mortgage 4 per cent bonds, due 1949	48,285.00	
50,000	New York, Westchester & Boston Rwy. Co., first mortgage $4\frac{1}{2}$ per cent bonds, due 1946	49,187.50	
50,000	Northern Pacific-Great Northern (Chicago, Burlington & Quincy collateral), joint 4 per cent bonds, due 1921	49,037.50	
50,000	Northern Pacific Rwy. Co., general lien railway and land grant 3 per cent bonds, due Jan. 1, 2047	33,101.25	
50,000	Oregon-Washington Railroad & Navigation Co., first and refunding 4 per cent mortgage bonds, due 1961	46,375.00	
30,000	Pennsylvania R. R. Co., general mortgage $4\frac{1}{2}$ per cent bonds, due June 1, 1965	29,837.50	
101,000	Pennsylvania R. R. Co., consolidated mortgage, $4\frac{1}{2}$ per cent bonds, due Aug. 1, 1960	105,608.12	
100,000	Southern Pacific R. R., first refunding mortgage, 4 per cent bonds, due 1955	92,148.75	
140,000	Union Pacific R. R. Co., first lien and refunding 4 per cent bonds, due June 1, 2008	128,722.50	
50,000	United Fruit Co., 4-year 5 per cent gold coupon bearer notes, due May 1, 1918	47,687.50	
112,500	United States Government First Liberty Loan of 1917	112,500.00	
	United States Government Second Liberty Loan of 1917 (2 per cent instalment)	1,900.00	
			1,916,153.09
24,422,500			24,313,825.15

ENDOWMENT.

Bonds (see schedule, page 54)	$22,119,222.55	Endowment			$22,000,000.00
Cash on deposit (page 52)	777.45	Profit, redemption of bonds			120,000.00
	22,120,000.00				22,120,000.00

COLBURN FUND.

Bonds (see schedule, page 54)	$80,295.00	Bequest			$77,755.74
		Profit, sale of bonds			1,295.00
		Interest collected		$6,403.61	
		Accrued interest purchased	$29.00		
		Expense of collecting	11.02		
Cash, on deposit (page 52)	5,119.33			40.02	
					6,363.59
	85,414.33				85,414.33

RESERVE FUND.

Bonds (see schedule, pages 54, 55)	$1,916,153.09	Appropriations, 1911–1917			$1,750,000.00
		Interest collected		$282,197.34	
		Accrued interest purchased	$19,286.02		
		Expense of collecting	1,842.58		
				21,128.60	
					261,068.74
					2,011,068.74
Cash, on deposit (page 52)	94,590.65	Loss, redemption of securities			325.00
	2,010,743.74				2,010,743.74

INSURANCE FUND.

Bonds (see schedule, page 54)	$198,154.51	Appropriations, 1909–1917			$188,000.00
		Profit, redemption of securities			67.50
		Interest collected		$32,459.12	
		Accrued interest purchased	$1,622.25		
		Expense of collecting	205.56		
				1,827.81	
					30,631.31
		Revertments			6,039.32
					224,738.13
Cash, on deposit (page 54)	4,312.68	Deduct losses by fire and cyclone, premiums			22,270.94
	202,467.19				202,467.19

REPORTS ON INVESTIGATIONS AND PROJECTS.

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1917, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.[1]

D. T. MacDougal, Director.

Progress in the development of the various subjects under consideration by members of the staff, assistants, and collaborators is adequately described in the following paragraphs, and in the interest of brevity no general summary is presented.

Conditions have operated to restrict field work during the year. All important stations as far eastward as the Graham Mountains, the Grand Canyon, and the Colorado River on the westward have been visited from the Desert Laboratory.

IMBIBITION AND WATER-RELATIONS OF PLANTS.

The Construction of a Biocolloid exhibiting some of the Water-Relations of Living Plants, by D. T. MacDougal.

A complete representation of protoplasm would doubtless reveal it as a very intricate complex of material which might be separable into a large number of substances or definite chemical compounds. The greater number of such substances would be seen to be of such nature that their formation, disintegration, or change would not be accompanied by much variation of the volume of the water included or held.

Growing protoplasts contain 98 per cent or more of water, and any inquiry as to the physical basis and chemical processes implied in growth would therefore be logically directed toward the substances which may adsorb and hold large proportions of water. This naturally focuses attention on the comparatively inert pentoses of the plant-cells as the basis of imbibition phenomena. Pure amorphous carbohydrate does not exist in the organism; it is always mixed with albumen and some of its derivatives, necessarily includes salts, and is continuously modified by respiration or other metabolic process, accompanied by varying states of acidosis or alkalosis.

The above assumptions have been used as a basis for experimentation for the purpose of constructing a mixture of colloids which would exhibit the imbibitional but not the osmotic phenomena of the plant.

Agar has been taken to represent the amorphous carbohydrate element, and to it have been added albumen, amino-acids, amides, and other compounds. Salts have been incorporated in the mixtures or dissolved in the solutions used to produce swelling.

Solutions of various mixtures were poured on glass plates in layers about 1 cm. thick and 3 by 5 cm. in area. Desiccation resulted in a reduction to a thickness of 0.1 to 0.3 mm. usually. The principal

[1] Situated at Tucson, Arizona.

axis of deposition of material was in the vertical, and the swelling in this direction would of course be correspondingly in excess of that in the plane of the sections. It is extremely unlikely that any of the colloidal masses of the cell are isotropic as to deposition or structure and the use of thin plates seemed a feature which might increase the similarity of behavior with that of the plant. The strands, sheets, or masses of material in the cell are of course mostly thinner than the plates used in the experiments, which, however, would affect speed of imbibition more than the total amount.

Trios of sections of sheets of the dried colloids 2 mm. to 4 mm. by 3 mm. to 6 mm. were placed in the bottom of Stender dishes or of heavy watch-glasses securely seated on iron cylinders. Triangles of glass were placed on the sections, and the vertical arms of auxographs were rested in a socket in the center of the triangles. Any change in thickness of the sections would be registered immediately.

The systematic endeavor to construct a colloidal mixture which would display some of the fundamental physical properties of protoplasm of plants has resulted in finding that a mixture of substances of two of the three more important groups of constituents, carbohydrates and proteins, shows the imbibitional behavior of tissues and tracts of protoplasts of the plant. The differential action of such biocolloids in solutions yields many striking parallels with growth. The general identity of constitution of these colloidal mixtures and of cell-masses, and the obvious similarity of their behavior, make it possible to correlate more closely the processes of imbibition, metabolism, and growth, and on the bases of their interrelation to interpret growth enlargement and incidental variations in volume and size of organs.

It is also to be suggested that the differential action which might ensue from the addition or subtraction of a nitrogenous compound from the carbohydrate body of protoplasts in special tracts, changing the imbibition capacity of chromosomes, of spindles or cell-plates, etc., may well play an important part in the mechanics of mitosis and cell-division.

Imbibition in Biocolloids as affected by Acidosis, Alkalosis, and Neutralization, by D. T. MacDougal.

Some systematic information as to the swelling of agar and gelatine in water, acids, alkalies, and salts with regard to concentration of the reagents is available as the result of work in the physics of simple colloids. The reactions of sections of living plants to similar solutions demonstrated that protoplasm shows a characteristic behavior which may be simulated fairly well by a mixture consisting of a base of an inert carbohydrate like agar and albumen or its derivatives, which for convenience has been designated as a biocolloid. The swelling of dried sections of biocolloids gives data which can not be anticipated by a con-

sideration of the known laws of imbibition of its components separately, but it is confidently predicted that with wider evidence the general behavior of a biocolloid may be foretold.

Preliminary tests of imbibition by biocolloids were made chiefly with a single concentration of the reagent, which is taken to lie within the possibilities of conditions in the cell. Extension of the investigation will necessarily include the delineation of effects of reagents down to the vanishing-point and up to various maxima, which may run as high as 0.05 M. in some cases. The general effect of concentration may be illustrated by the swellings of a biocolloid of 90 parts agar and 10 parts glycocoll, which were as follows:

		M/100	M/50	M/10
	p. ct.	*p. ct.*	*p. ct.*	*p. ct.*
Water	3,266	....	....	....
Potassium nitrate	.....	1,800	1,733.2	1,333.3
Potassium chloride	.....	1,733.3	1,666.6	900
Calcium nitrate	.....	1,333.3	1,200	800

From this it may be seen that an inhibiting effect on imbibition in the colloid was exerted by these salts, the effect increasing with the concentration and the least swelling taking place in the calcium compounds.

It is probable that some organs and more than probable that some cell-structures contain a larger proportion of albumen or its derivatives than of amorphous carbohydrate, in which case the effect of concentration of salts on imbibition might be illustrated by the swellings of a biocolloid consisting of 90 parts gelatine and 10 parts mucilage from *Opuntia*, which were:

		M/100	M/50	M/10
	p. ct.	*p. ct.*	*p. ct.*	*p. ct.*
Water	589.4	.....	.....	.....
Potassium nitrate	.....	485.5	455.3	698.2
Potassium chloride	.....	473.2	473.2	401.9
Calcium chloride	.....	473.2	.....	348.2

The swelling increases with concentration of potassium nitrate within the range used and appears to decrease slightly within similar concentrations of potassium chloride, and is checked to a greater extent by calcium chloride, although the last-named solution would have a slightly alkaline reaction due to the hydrolysis of the salt.

Nucleinic acid is a constituent of the nucleus, and its swelling reactions carry much interest. The results were as shown at top of the following page when combined in proportion of 10 parts nucleinic acid to 90 parts agar:

	Percentages.		
Distilled water	1,400	1,025	1,475
Potassium nitrate, 0.01 M		900	800
Potassium nitrate-citric acid, 0.01 M		650	675
Potassium citrate, 0.01 M		850	750
Potassium citrate-citric acid, 0.01 M		725	...
Citric acid, 0.01 M		700	625
Sodium hydrate, 0.01 M		1,000	925

Such a mixture is seen to swell most in distilled water, while the proportionate swelling in alkali is very high, being greater than that in the salts tested or in acid. Next, it is apparent that the two potassium salts produce or allow an amount of imbibition not very much short of that in the alkali. The acidification of the salts practically reduces the swelling to the proportion displayed by the acid alone.

It appeared to be important to form a series in which the swelling in alkaline salts would be included. The first measurements were made with dried plates a week old of agar 90 parts, nucleinic acid 10 parts, 0.2 mm. in thickness. The swellings were as follows:

	Percentages.	
Distilled water	950	1,100
Potassium nitrate, 0.01 M	650	550
Potassium nitrate-citric acid, 0.01 M	575	500
Citric acid, 0.01 M	575	450
Potassium nitrate-potassium hydrate, 0.01 M	900	750
Potassium hydrate, 0.01 M	850	800

The effects of a similar series of reagents were tried upon disks from growing joints of *Opuntia* with the following results:

	P. ct.
Distilled water	10.8
Potassium nitrate, 0.01 M	8.7
Potassium nitrate-citric acid, 0.01 M	9.8
Citric acid, 0.01 M	9.2
Potassium nitrate-potassium hydrate, 0.01 M	10.4

The differences are not very great, yet it is to be noted that they are in the same direction as those of the biocolloid (agar-nucleinic acid). The imbibition is greatest in distilled water, scarcely less in alkaline potassium nitrate, and definitely less in acids and neutral salts. All of the above tests were made at temperatures of 15° C. to 18° C.

The data cited above serve to show some of the more obvious features of imbibition in a biocolloid as affected by conditions similar to those supposedly prevalent in living plants.

Colloidal Phenomena in the Protoplasm of Pollen Tubes, by Francis E. Lloyd.

The study of the swelling rates of gelatine at various concentrations of acids and alkalies has been continued in order to throw light on the behavior of pollen tubes grown in such reagents in the presence of high constant concentrations of cane sugar. The results are briefly summarized as follows:

Within the limits of concentration N/10 to N/2560 of the reagent (acid or alkali) the maximum swelling rates and maximum total swelling in acids occur at N/10 (malic acid) to N/320 (hydrochloric acid) and for alkalies at about N/80. The organic acids cause maximum swelling at higher concentrations than the mineral acids, apparently in direct relation to the degree of dissociation. It is also to be noted that the maximum swelling rates during the earlier periods occur in higher concentrations than later, the movement of the high point of the curve being greater for mineral than for organic acids. It may be suggested that this results from the partial adsorption of the acid by the gelatine, with consequent dilution and greater dissociation of the remainder of the reagent. There is a similar but less movement of the maximum rates of swelling in alkalies.

At lower concentrations of acids and alkalies there is a repression of swelling rates, especially in hydrochloric acid, as observed by Proctor (Jour. Chem. Soc. London, vol. 109–110). This is always greater for acids, the repression being sufficient to lower the rates materially below that for water, while in alkalies the rates are about equal to or only slightly less than that in water. The concentrations in question range below N/640, the minimum rates found being, *e. g.*, for sulphuric acid N/1280, for hydrochloric acid N/2560, acetic acid, N/640, formic N/1280 (temp. 20° C.). During the later period of swelling the repression may or may not be overcome, it being permanent in acids and transient in alkalies. With the above facts in hand, it has been sought to determine how far a parallelism is to be found between the behavior of protoplasm in pollen and that of gelatine.

Proceeding from the results previously attained (Carnegie Institution Year Book for 1916, p. 67), the effects of a series of acids (hydrochloric, acetic, malic, citric, formic, and oxalic) have been determined for concentrations N/200 to N/25,600 in association with cane sugar in concentration of 16 per cent.

In these solutions no growth occurs at concentrations at or above N/3200 of the acid component. Below that limit the rate of growth is inversely as the concentration. The rate and total amount of growth possible for any concentration varies with the acid, it being least at the higher concentrations for formic and oxalic and highest for acetic. It will be noted that these concentrations are very much lower than those dealt with by Long, MacDougal, and Spoehr, in studying acidity, respiration, and swelling in cacti and in biocolloids.

There is evidence, furthermore, that the growth-rates of pollen tubes are limited by their ability to make use of the swelling effects of the acids in question. At the higher concentrations at which growth may occur, bursting of the tubes supervenes. At still higher concentrations, namely, above N/3200, shrinkage, in amounts varying with the concentrations, occurs.

With sodium hydrate it has been possible to find a point of concentrations (*ca.* N/3200), within the limits above mentioned, at which maximum growth occurs. The parallelism of behavior between gelatine and the protoplasm of pollen tubes when expressed in terms of accomplished growth is therefore more apparent in the case of alkaline than of acid media.

Experiments upon the Imbibitional Swelling of Marine Algæ, by J. M. McGee.

Since agar has been used in these laboratories as a basal carbohydrate material in many mixtures prepared for the study of colloidal swelling and imbibition, it was thought advisable to investigate the swelling of some of the red algæ from which such material is derived, in various solutions. The species which seemed most promising, because of their form and their relationship, were *Iridæa laminarioides*, *Gigartina exasperata*, and *Gigartina mammillosa* var. *dissecta*, all of which grow on the rocks in Carmel Bay in large amounts.

Trios of sections of the laminæ of these species were swelled in various solutions and their increase registered by the auxograph. These marine algæ have a normal balance enabling them to exist in sea-water which contains about 3.50 per cent total salts. The effect of the various substances on imbibition in these plants was therefore obtained by adding them to sea-water in such quantities that they formed hundredth-normal solutions. This practice made possible comparisons with swelling measurements made upon mixtures of agar with various proteins, gelatine, etc., by Dr. MacDougal, the results of which will be found elsewhere in this report. The potassium nitrate and citric acid were used in a total hundredth-molar solution.

The results of the swellings are as follows:

Name of alga.	Thickness.	Per cent swelling in—		
		Sea-water plus NaOH N/100	Sea-water plus HCl N/100	KNO_3 plus citric acid M/100
Iridæa laminarioides:	*mm.*			
Tip of lamina	0.4	0	0	537.5
Do	0.4	25	31	175.0
Gigartina mammillosa var. dissecta:				
Tip of frond	0.5	10	?	60
Do	0.5	50	15	60
Lateral swelling	...	10	22.2	17
Gigartina exasperata:				
Young lamina (fresh)	0.6	33.3	58.3	150
Do	0.6	16.6	20.8	200.0
Do	0.6	12.5	50	158.6
Young lamina (kept 3 days)	0.7	3.5	7.1	132.8

The imbibition of *Iridæa laminarioides* indicates a high proportion of amino-acids, while the species of *Gigartina* studied probably contains a higher proportion of pentoses or agar-like substances.

Smooth young laminæ of *Gigartina exasperata* were washed in fresh running water for 24 hours to remove most of the sea-salts and then dried between filter-papers. Trios of sections of these dried laminæ were swelled in N/100 HCl, in N/100 NaOH, in distilled H_2O, and in the sea-water solutions mentioned above, with results as follows:

Per cent of swelling.

Thickness, mm.	0.1016	Thickness, mm.	0.0508
Sea-water + NaOH N/100	393.7	NaOH N/100	2,755.9
Sea-water + HCl N/100	590.5	HCl N/100	2,066.9
Distilled H_2O	1,476.0	Distilled H_2O	4,330.7

A chemical analysis of this dry material gave the following results:

	Average p. ct.
Ash (salts)	11.70
Moisture	15.70
Gelatine-like material	14.95
Carbohydrates—agar-like material	57.65

The gelatinous or mucilaginous material was extracted from each of these species by heating several grams of the plants, which had previously been washed for 24 hours, dried, and finely ground, for 2 or 3 hours at the temperature of boiling water, and then straining through four thicknesses of muslin. The extract so prepared was a pale straw-colored viscous fluid which would not solidify completely when cold but became very thick and viscous. The extract from all of the species was fairly uniform in character. Plates were made from 9 grams of agar and the extract from 10 grams of the dry *Gigartina exasperata*. Trios of sections from these plates were swelled. The proportionate increase in water in the solutions is characteristic of a mixture of agar with a small proportion of albumen or protein as indicated by the data obtained by MacDougal. This implies that the extract of the alga was chiefly gelatinous and probably consists largely of amino-acids. The swelling of the dried sections alone, however, is more characteristic of agar.

Thickness of sections, mm.	0.2286	Thickness of sections, mm.	0.2032
NaOH N/100, per cent swelling	809.0	NaOH N/100, per cent swelling	910.4
HCl N/100, per cent swelling	809.0	HCl N/100, per cent swelling	984.2
Distilled H_2O, per cent swelling	2,296.0	Distilled H_2O, per cent swelling	2,460.0

Imbibition of Gelatine and Agar Gels in Solutions of Sucrose and Dextrose, by E. E. Free.

It has been shown by MacDougal that a biocolloid consisting chiefly of agar and a small proportion of some nitrogenous substance exhibits the principal water-relations of living plants. The experiments on this subject have dealt chiefly with the effects of salts, alkalies, and acids upon the swelling of these colloids and of living material. All the work upon this subject has had for its chief purpose the simulation of conditions in the plant-cell in which sugars are almost universally present. Much has been written concerning their osmotic action. A comprehensive series of swelling tests was made with sucrose and dextrose under properly guarded conditions upon the swelling of biocolloids consisting of varying proportions of agar and gelatine.

For the sugar solutions having concentrations less than 25 per cent, the results do not differ from those for distilled water more than is explainable by the accidental variation normal to the method when the temperature is not controlled precisely. The effects of N/100 acid and alkali found by MacDougal were many times the variations here observed, and one may conclude that neither sucrose nor dextrose, in concentrations under 25 per cent, has any important effect on the swelling of gelatine-agar gels in water—important, that is, in comparison with the effects of acids or alkalies. With sugar concentrations of 50 per cent the data show a markedly lessened swelling of all the gels in sucrose and of the two low-gelatine gels in dextrose. It may be that the two high-gelatine gels also swell less in 50 per cent dextrose, but the decrease is not certainly determinable from the single test which was made. This decrease in swelling in concentrated sugar solutions is to be expected from analogy with the osmotic behavior of such solutions and does not indicate any specific effect of sugar, either on the swelling or imbibition capacity of the gels themselves.

The Transpiring Power of Plants, by Edith B. Shreve.

Recent improvements in the method for determining the index of transpiring power of plants by means of cobalt-chloride paper have resulted in the use of the method by several investigators in different parts of the United States.[1] Since these workers are using the tripartite slips made from standardized paper which was manufactured in Dr. Livingston's laboratory in Baltimore, it is hoped that their results will be comparable and that they will lead toward a more exact knowledge of the transpiring power of various plants under many environmental conditions. The method is also being used to determine the drought-resistant qualities of different strains of economic plants.

[1]Livingston, B. E., and E. B. Shreve. Improvements in the method for determining the transpiring power of plant surfaces by hygrometric paper.

In this laboratory experimentation is under way to compare the index of transpiring power as determined by the cobalt tripartite slips (I) with the transpiring power as determined by the rate of the loss of weight from the plant to the loss from an atmometer (T/E). Extensive tests have thus far been made on five species of plants, both methods being used simultaneously on every plant. In general, the graph representing the daily march of I has the same shape as the curve representing the daily march of T/E. Slight variations occur frequently, especially in the morning, when the tripartite slips often show the beginning of the customary decrease one or two hours before it appears in the other curve. In other words, the time of the beginning of incipient drying can be detected sooner by means of the cobalt slips than by the weighing method. The results of the experiments show that, for the species investigated at least, a comparison of the transpiring power of different plants may be made as accurately with the cobalt tripartite slips as by the use of the weighing method. The fact that the cobalt slips may be used on plants naturally rooted in the earth makes comparisons by this method more reliable than by the other.

As more data are being accumulated by the simultaneous use of the two methods, it is becoming more and more probable that a numerical constant will be found, the use of which will enable the experimenter to compare the actual amounts of water lost per unit area from various plants as well as their transpiring power. The search for this constant is being made as follows:

Transpiration, T, per unit area per unit time is obtained by weighing plants in sealed pots at 2-hour intervals; evaporation, E, is obtained by loss of weight from a white atmometer of the Livingston type; the ratio T/E represents the transpiring power. Then for half an hour in the middle of each transpiration period from 10 to 20 leaves on the same plants are tested with the cobalt slips. The time required for each slip to make the proper color change on the leaf is divided by the time required for the same slip to make the color change over a standard surface at the same temperature; the reciprocal of this number represents the index of transpiring power (I). When the values for T/E are divided by the corresponding values for I, numbers are obtained which approach a constant. If $\frac{T/E}{I}=c$, then $I \times c = T/E$; now, since E can be obtained from atmometer readings T, the actual water-loss per unit area can be found. A much larger number of determinations must be made before the validity of the constant can be confirmed, but it now seems reasonably certain that by testing many leaves in each experiment a constant can be found the use of which will admit of at least an approximation of the actual amount of water lost when the cobalt slips are used. This constant appears to be in the neighborhood of 0.017.

The chance for the greatest error in the use of the cobalt slips now rests in the assumption that the leaf and air temperatures are the same at the time of the tests. A new method for the determination of leaf temperature is being developed which it is hoped will reduce this danger of error. Further search for the exact value of the constant will await the developments of the leaf-temperature method.

The experiments mentioned above have brought out very clearly that when it is desired to make a comparison of the transpiring powers of plants of different species or strains, it is necessary to obtain the daily march of transpiring power, and that little reliance can be placed upon a comparison of isolated readings, this being true no matter which method is used. Furthermore, when potted plants are used it is never safe to draw conclusions from the behavior of one or two plants. When the cobalt slips are used care must be taken to test several leaves of all the ages and sizes that exist on the plant.

The Relation between Water Loss by Evaporation and Water Gain by Absorption in Colloidal Gels, by Edith B. Shreve.

As was noted in the report of last year,[1] preliminary experiments on the tissue of *Opuntia versicolor* showed the probability of a direct relation between the water-absorbing power and the power to withhold water against the evaporative forces of the air. Further experimentation has now confirmed this for tissues of *Opuntia versicolor* and *O. blakeana* (?). It was also mentioned last year that work had been begun on the testing of this relation for non-living colloidal gels. Plans are laid for the use of a number of gels, particularly of carbohydrate constitution, but the work has not yet progressed beyond tests with gelatine, owing to the unexpected necessity of investigating the nature of the absorbing power of gelatine itself.

It was easily shown that the greater the water-content of the gelatine the less the absorbing power and the greater the evaporating power until a concentration is reached where the gelatine loses water at the same rate as a similar water-surface.

The work of Hofmeister and others has shown that the presence of acids and certain salts in a solution surrounding gelatine increases the absorbing capacity of the gelatine, while that of certain other salts decreases it. The plan was to make up gelatine in various concentrations of these salts, *i. e.*, including the salts within the gel, and ascertain if those salts which increase absorption decrease evaporation, and *vice versa.* The results show conclusively that a large increase in the absorbing power is accompanied by a small decrease in the evaporating power, *i. e.*, by an increased ability of the gelatine to resist the evaporative force of the air. The presence of N/100 HCl reduced the

[1]Carnegie Inst. Wash. Year Book 1916, p. 66.

evaporation rate to half that of neutral gelatine. However, it developed that sodium sulphate, sodium acetate, and sodium tartrate, salts which are given in the Hofmeister series as decreasing the adsorption, also decreased the evaporation rate. But when parallel tests of absorption were made it appeared that when these salts were made up in the gelatine and the gelatine placed in distilled water, they too increase the absorbing capacity of the gelatine. The accompanying tables give samples of the results obtained. Corrections were made for loss or gain due to exchanges between the gelatine and the surrounding liquids.

Average gain in weight per hour per gram of gelatine for first 3 hours.

	No. 1.	No. 2.
2 grams dry gelatine to 5 c.c. water in distilled water..................	0.588	0.576
2 grams dry gelatine to 5 c.c. water in M/2 sodium sulphate............	0.532	0.550
2 grams dry gelatine to 5 c.c. M/2 sodium sulphate in distilled water..	0.930	0.910

Average gain in weight per hour per gram of dry gelatine for first 3 hours.

	No. 1.	No. 2.
2 grams dry gelatine to 5 c.c. water in distilled water....................	0.580	0.585
2 grams dry gelatine to 5 c.c. water in M/2 sodium tartrate.............	0.331	0.326
2 grams dry gelatine to 5 c.c. water in M/4 sodium tartrate............	0.465	0.472
2 grams dry gelatine to 5 c.c. M/2 sodium tartrate in distilled water...	0.740	0.748
2 grams dry gelatine to 5 c.c. M/4 sodium tartrate in distilled water...	0.690	0.710

The work was scarcely begun before it became evident that the absorption rate of gelatine is greatly influenced by its history from the time of "setting" to the beginning of the tests. Before comparable results could be obtained the influence of this history had to be investigated.

As was to be expected, the water-content of the gelatine at the beginning of the absorption strongly influences the rate of water intake, so that great care must be taken to have all the gelatine of the same water-content at the start. Even when the gelatine used has the same water-content at the beginning of the experiment, its ability to absorb water still depends upon its water-content when it was made up, as the table on page 70 shows. Several lots of gelatine were made up to the concentrations indicated in the table and all lots allowed to evaporate water at room temperature until tests showed that they had attained the same water-content. Then pieces of the same size

Percentage increase of original thickness, and the water-content per gram of dry weight of gelatine, at ends of periods indicated and at three percentages of concentration.

Period.	Increase of thickness.			Water-content.		
	10 per cent.	20 per cent.	33 per cent.	10 per cent.	20 per cent.	33 per cent.
16 hours.	780	530	490	.....	.....	.....
40 hours.	930	650	520	.....	.....	.....
136 hours.	1,320	1,050	860	98.4	.....	47.1
160 hours.	[1]	1,160	1,025	.....	178.0	100.0

[1]Dissolving.

and thickness were placed in water and their increase in thickness measured at intervals. Only sample readings are given in the table.

Two pieces of gelatine may have had the same water-content when made up and also at the beginning of the test and even then may not absorb at the same rate if their histories between the time of making and the beginning of the absorption were not the same. Suppose a 20 per cent gelatine solution is made up, divided into two lots, and allowed to set. Let lot No. 1 be placed in a covered dish, so that no loss of water by evaporation takes place. Let lot No. 2 be allowed (1) to lose water to the air until it has reached either complete or partial air-dryness, and (2) to absorb water until its water-content has returned to the original amount. If now the two pieces are allowed to absorb water simultaneously, No. 2 will absorb at a higher rate than No. 1.

The previous history of the gelatine used affects also the distribution of the increase in size among the several dimensions of any given piece, as will be seen from the following results obtained from a large number of experiments. The tests were made on gelatine of several concentrations from 10 to 33 per cent. Rectangular blocks, 2.0 × 0.35 × 0.35 cm. were cut from the gelatine as soon as it had set.

(1) Pieces of the size and shape mentioned above swell equally in thickness, breadth, and length, if no appreciable amount of water has evaporated from the gelatine since it "set."

(2) Similar pieces, when placed on a glass plate with the largest face in a horizontal position and allowed to lose water by evaporation at ordinary temperatures, shrink about twice as much in the two short dimensions as in the long one, shrinkage being based on percentage of the original size.

(3) When the pieces mentioned under paragraph 2 are allowed to absorb water they swell in the same relative proportions that they shrink. That is, the increase in size for the two short dimensions is about twice as great for the long dimension. This distribution of increase continues for at least 63 hours after the gelatine has attained its original water-content.

(4) If pieces of the same size and shape as above are cut from freshly made gelatine and hung on a thread with the long axis in a vertical position, where they are exposed to equal evaporation on all sides, the same distribution of decrease in size and subsequent increase in water takes place, as was found under paragraphs 2 and 3.

(5) If gelatine is poured into a large dish or on a glass slab and allowed to lose water by evaporation before pieces are cut for tests, the decrease in thickness far exceeds the decrease in the other directions, and the subsequent swelling when pieces are placed in water follows the same proportion. For example, 15 per cent gelatine when treated in this manner showed swelling to the following amounts: thickness 181 per cent, breadth 15 per cent, length 6 per cent.

Other more or less obvious precautions must be heeded in order to obtain comparable results, and by no means least of these is the necessity for obtaining all the gelatine from the same source and of making frequent tests for variations in acidity. It has been known for some time that the greater the surface exposed the more rapid the intake of water, but it was necessary to find how much this fact needed to be taken into account in obtaining comparable results. It was found that pieces of the same area might vary in thickness from 0.01 to 0.36 cm. without showing an appreciable difference in percentage rate of increase in thickness, total volume, or gain by weight. On the other hand, pieces from 0.01 to 0.23 cm. in thickness, whose areas varied from 1.62 sq. cm. to 1.82 sq. cm., showed difference in rate of increase for at least 48 hours, but after this time the total increase was the same, whether measured by height, volume, or weight.

The above conclusions have been given at some length not only because they must be taken into consideration in all experimentation with the swelling of gelatine, but also because it seems that they place an entering wedge into the problem of the mechanism of the absorption of water by gels. Furthermore, they give a new view of the complexity of the factors which may operate to control rate and direction of growth as well as absorption and transpiration in the highly complex colloids of the plant.

The Physical Basis of Parasitism, by D. T. MacDougal.

The earlier experimental studies of the author led him to conclude that a necessary condition of parasitism was a higher osmotic concentration of the species which could become parasitic. Harris and Lawrence have carried out an extensive investigation of the problem on Loranthaceous parasites in the Jamaican rain forests, and in a paper now in press have shown that in case of plants growing under these conditions the parasite is generally but not invariably characterized by a higher osmotic concentration of its fluids. They also show that on theoretical grounds higher osmotic pressure of the tissue fluids

is not a necessary prerequisite of successful parasitism in the case of a species living under natural conditions.

That the absorbing organs of a plant might withdraw liquids from tissues of another plant, the sap of which had a higher concentration, is also to be concluded from the results of recent work on imbibitional phenomena at the Desert Laboratory.

Extended series of measurements established the fact that a mixture consisting of 90 per cent or more of agar and 10 per cent or less of protein, albumen, gelatine, tyrosin, or cystin takes up water in a manner remarkably parallel to that of pieces of tissue of living plants. This similarity is regarded as more than a coincidence. The plant protoplast consists largely of carbohydrates of the pentosan group, with which are mixed varying proportions of nitrogenous material, which may be in the form of protein, amino-acids, etc. Such a mixture would have identical relations to water, either as swelling plates in the laboratory or as sheets or strands of colloid in the cell.

A number of agencies or conditions are found to affect the total amount of water which may be taken up by this biocolloid mixture. For example, some mixtures absorb slightly more water in acidified solutions than in alkaline, and many times as much from neutralized as from either acid or alkaline solutions. Some salts in the solution increase imbibition and some lessen it.

These generalizations rest upon measurements made by the following method: Small sections of dried plates of a mixture of biocolloids were placed in trios in glass dishes into which various solutions might be poured. Triangular pieces of thin glass were laid on these pieces. The swinging vertical arm of an auxograph rested in a socket in the middle of this plate. When the entire preparation was in readiness and the pen at the other end of the compound lever was marking properly on the ruled paper of a revolving cylinder, the solution was poured into the dish. The rate, course, and amount of expansion was recorded by an inked line. (See Mem. N. Y. Botan. Garden, vol. 6, pp. 5–26, 1916, for a description of instrument.)

The invaded tracts of the host are usually composed of expanded vacuolated cells in which osmosis resulting from the solutions in the vacuoles is the dominant hydrostatic agent, although the colloids suspended in these vacuoles and the denser colloids of the cytoplasm have their own imbibitional capacities.

The younger cells of the haustorium which push into such masses are probably not yet vacuolated. Absorption by them is almost entirely by imbibition, and this would be carried on against any probable osmotic action of a vacuolated cell. Thus, a thin plate of biocolloid absorbed water from a solution of potassium nitrate which had an osmotic coefficient of 60 atmospheres swelled about 400 per cent in volume in 15 hours.

A second feature, the force of expansion of the invading protoplasts, would be no less important. The pressure set up, like that of a swelling seed, would be great enough to cause mechanical penetration of the host, as it would be far greater than any force attributable to osmotic action.

After the haustorial development has carried that organ to a mature stage the nutritive contact with the host is one in which osmosis doubtless plays an important part. The proportion of nitrogenous substance in the parasite or the acidity of the concentration of salts might be the determining factors in both the making and maintenance of a nutritive couple of host and parasite. (See MacDougal and Cannon, Conditions of Parasitism in Plants, Carnegie Inst. Wash. Pub. No. 129, and MacDougal, The Beginnings and Physical Basis of Parasitism, Plant World, August 1917.)

PHOTOSYNTHESIS, METABOLISM, AND GROWTH.

The Carbohydrate Economy of Cacti, by H. A. Spoehr.

The investigations on the carbohydrate metabolism of the cacti have been continued, repeating with improved methods and extending the previous studies, especially in regard to the seasonal variations in the carbohydrate balance. Owing to the fact that the material used (the platyopuntias and *Opuntia versicolor*) lends itself so admirably to experimentation, it has been possible to gain an insight into various phases of the carbohydrate economy of plants which as yet has not been possible from work with thin leaves.

The purpose of this work, begun two years ago, is primarily to gather data and general facts which can be brought to converge for an attack on the problems of photosynthesis. Preliminary experiments, carried out several years ago, indicated clearly that prerequisite to a rational approach on the problem of the manner in which sugars are formed in the chlorophyllous leaf is a clearer understanding of the conditions governing the equilibria and mutual transformations of the various groups of carbohydrates in the leaf, as well as of the fate of these substances in the general metabolism.

From these studies it becomes evident that the amount (or the proportion to the total) of certain sugars present in a leaf after insolation can not be taken as an indication of the rate at which these sugars are formed in the photosynthetic process, as has been almost universally done, for under varying conditions of water-content and temperature, such as occur in a leaf in the sunlight, there is a consequent shifting of the carbohydrate equilibrium, resulting in the removal of one or the accumulation of another group of sugars according to circumstances. Therefore, these conditions (*e. g.*, water-content and temperature) either must be kept constant or, what is more feasible, the equilibrium under the particular circumstances must be established

before any conclusions can be drawn as to the immediate source of any particular sugar. Thus, for example, it is not justifiable to conclude that saccharose is the first sugar formed in photosynthesis, merely on the basis of the analyses of the insolated leaf, without accurate knowledge of the other sources and conditions which lead to the accumulation of this sugar. Again, the mere fact that the total pentoses generally accumulate in the older portions of a plant is no evidence that these substances are to be regarded as waste products coming from the incomplete respiration of hexose sugars.

These conditions are further complicated by the inherent physiological differences of the various kinds of plants, such as that of plants which produce starch easily having relatively only very little soluble reducing and non-reducing carbohydrates, while plants which form little or no starch accumulate relatively large quantities of these sugars. Also, there is now some indication that not only is the rate of the photosynthetic process influenced by the accumulation of synthesized material, but the process itself seems to require some available food material. This question, it is hoped, will be one of the first subjected to thorough investigation.

The variations in the carbohydrate equilibrium unquestionably exert a very profound influence on many of the most important physiological activities of the organism. It is not possible, however, to indicate any single factor or substance to which can be ascribed such activities as the formation of new shoots or growth in general, nor is such a state of affairs likely to exist, physiological activity in all probability representing the "resultant of forces." The manner in which this great complex of chemical equilibria is regulated under varying external conditions allows some insight to be gained into the dynamic processes of the living organism as yet but dimly visible with the aid of chemical and physical conceptions.

And finally, the conclusions indicate with some definiteness that the results of the investigations of the more intricate phases of plant metabolism are pregnant with concepts which, when considered in their practical application, are not without value to the culture of plants grown for their various commercial products.

The method employed consisted essentially in the analysis of relatively large amounts of the cactus material which had grown under normal circumstances or had been subjected to special treatment or controlled conditions. The analyses embrace the rate of carbon-dioxide evolution at 28°, the dry weight, total sugars, total polysaccharides, total hexose sugars, hexose-polysaccharides, disaccharides, monosaccharides, hexoses, total pentose sugars, pentosans, pentoses, cellulose, and ash, as well as a series of micro-chemical tests on starch formation and utilization. From these data the condition of equilibrium of these various components can be readily calculated.

METHODS OF SUGAR ANALYSIS APPLICABLE TO PLANTS.

Early in the course of this work it became evident that existing methods of analysis of plant material were open to serious error. It was found that the material must be very quickly dried in order to destroy at once all enzyme actions, which by the usual methods of drying are greatly accelerated for some time by the heat before the material is killed. One per cent hydrochloric acid for hydrolysis proved to be the best; this completely hydrolyzes the polysaccharides, its effect on cellulose is slight, much less than other acids, as sulphuric acid. In making the alcoholic extractions it is exceedingly important that the acids of the plant material be neutralized with calcium carbonate; the addition of alkalies, as, for instance, ammonium hydroxide (commonly used), leads to molecular rearrangements. Even under the best of conditions it is doubtful whether the various hexoses in a plant can be accurately determined on account of the rearrangement of these sugars.

A study of the various methods of determining pentoses showed that these are open to several sources of error, and that this group of sugars can be determined with any degree of accuracy only after the removal of all hexose sugars by means of fermentation.

A special method has been devised for use with the alkaline copper solutions for all reducing sugars. The reduction is carried out, under definite and precise conditions, in a centrifuge tube of special design. This is graduated on the neck and provided with a glass stopper. After the reduction has taken place, the tube is cooled and the solution made up to volume and thoroughly mixed. The tube is then centrifuged, which results in a compact sedimentation of all cuprous oxide; the supernatant liquid is perfectly clear, and the remaining copper therein can be accurately determined by means of the thiosulphate method. By the employment of this method most of the usual sources of error incident to the use of copper solutions for the determination of sugars are avoided and exceedingly accurate results are obtainable with even very small quantities of sugar.

SEASONAL VARIATIONS IN THE CARBOHYDRATE CONTENT OF CACTI.

The vegetation of the desert is exposed to extreme climatic variations. The influence of the various climatic factors on organisms has been extensively studied at the Desert Laboratory from the physical-physiological, ecological, and genetic considerations. Many of the reactions noted in these studies have their origin in the more deep-seated metabolic activities induced by changes in the external conditions. In the cacti, as in most vegetable organisms, the nutritional and plastic material is predominantly of carbohydrate nature. The formation of this material, as well as the nature and rate of its metabolic rearrangements and disintegration, are profoundly affected by the climatic complex. The total effects of the various climatic factors

can be interpreted only by means of an analysis of the influence of the individual factors. The data now available are in the form of monthly analyses of joints from the same plant, in each case, and joints of the same age, formed in 1916:

Seasonal variations in the carbohydrate equilibrium of Opuntia sp. expressed in percentages of the dry material.

	Jan. 11.	Feb. 16	Mar. 17.	Apr. 25.	May 22.
Dry weight	22.20	22.30	19.50	24.30	25.25
Total sugars	19.10	21.32	28.05	32.40	30.15
Total polysaccharides	15.10	15.80	20.10	29.84	28.38
Total hexose sugar	14.95	14.90	22.16	22.70	17.08
Disaccharides	1.27	1.74	0.93	0.41	0.48
Hexoses	2.59	3.56	6.87	1.86	0.28
Total pentoses	4.73	6.07	5.55	9.15	12.34
Pentosans	4.40	5.51	4.75	8.68	12.17
Pentoses	0.43	0.55	0.82	0.48	0.16
Monosaccharides	3.02	4.11	7.69	2.34	0.44
Hexoses to hexose polysaccharides	.248	.357	.457	.090	.018
Total pentoses to total sugars	.248	.283	.198	.283	.409

By the beginning of July the new joints, formed in March, have, for all practical purposes, matured—that is, they show but very slight variation from the joints of the same plant one year older. In fact, the new joints become autonomous very early in their development: young shoots 3 cm. long, when cut from the parent joint, develop normally on nutrient solution. Temperature and the water-content of the joints are principal factors influencing the carbohydrate equilibrium. Among other features, noteworthy in the results of seasonal variation, are the conditions of the joints in March, when new joints appear, particularly the very high percentage of monosaccharides.

EFFECT OF TEMPERATURE ON CARBOHYDRATE EQUILIBRIUM.

In general an increase in temperature results in an increase in the katabolic and respiratory processes of a plant, which means that the available simple carbohydrates, the monosaccharides, are more rapidly used up. The monosaccharides are replaced by drawing on the stored polysaccharides by means of enzymatic inversion. At the temperatures which prevail in the plant in the summer, sometimes as high as 55° (see McGee, J. M., Rept. Dept. Bot. Res. Carnegie Inst. Wash., 1916, p. 73) in the cacti, the total reserve of carbohydrates would be rapidly depleted and the plant would be in a state of exceedingly high respiratory activity. There is, however, some evidence that the rate of monosaccharide and disaccharide replacement is reduced at these higher temperatures, so that, as it were, there exists an automatic adjustment which tends to close the valve from the store of polysaccharides, permitting a smaller rate of flow of inversion from

polysaccharide to monosaccharide, and resulting in a relatively reduced rate of consumption and consequent conservation of the total stored food material. Thus, for example, two identical sets of *Opuntia* joints kept in the dark, the one (A) at 28°, the other (B) at 12° for 5 weeks showed the following values in percentages of the dry material:

	A	B
	p. ct.	*p. ct.*
Dry weight	33.00	33.60
Total polysaccharides	16.00	16.63
Total hexose sugar	6.62	7.11
Hexose polysaccharides	5.49	5.47
Monosaccharides	0.70	1.01
Disaccharides	0.73	.96
Hexoses	0.48	0.81
Total pentoses	10.13	10.74

It is evident that although the total hexose sugars and the total polysaccharides are a little lower in A than in B, the proportion of monosaccharides to total polysaccharides is: $A = 0.044$ and $B = 0.061$; and the proportion of hexoses to the hexose polysaccharides is: $A = 0.087$ and $B = 0.148$. The influence on the pentose equilibrium is not nearly as marked as on the hexose sugars. The importance of these results on the effect of temperature on the carbohydrate equilibrium for further experimental work on the sugars produced in photosynthesis and on the problems of translocation of food material is self-evident.

EFFECT OF WATER-CONTENT ON CARBOHYDRATE EQUILIBRIUM.

The seasonal variations of the carbohydrate-content of the cacti are markedly affected by the rainfall. These plants respond quickly to available water, and the changes in the carbohydrate-content occur especially at the times of the well-defined periods of rainfall. With decreasing water-content the proportion of monosaccharides and disaccharides decreases; conversely, with increasing water-content the equilibrium is shifted in favor of the simple sugars. Variations in the water-content are associated with great differences in pentose sugars. These show a decided increase both in actual amount and in the proportion to the total sugars as the water-content of the plant diminishes, and a decrease as the plant takes up more water. Thus, lower temperature and higher water-content cause the carbohydrate equilibrium to shift in the same direction. In view of these facts most of the features of the seasonal variations can be understood.

Experimentally these phenomena can be clearly reproduced by allowing one set of similar joints to absorb water, while another set is kept dry under otherwise identical conditions. In view of these results and those on temperature many of the apparently contradictory conclusions regarding the first sugar formed in photosynthesis and the subsequent metabolic changes thereof can be reconciled.

CARBOHYDRATE EQUILIBRIUM DURING STARVATION.

The course of carbohydrate consumption during starvation of joints of *Opuntia* sp. has been followed through two periods of eight and six months, the joints being kept in the dark, without water, and at constant temperature, 28 C°. After about the first month the water-content remains fairly constant. The proportion of the various sugars to each other maintains a surprising regularity as the depletion proceeds; hexose and pentose sugars are consumed at the same relative rates, indicating clearly the use of the latter.

	Dec. 20.	Feb. 12.	Mar. 2.	Mar. 22.	Apr. 20.	May 12.
	p. ct.	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
Dry weight	31.50	36.80	36.20	40.13	40.50	37.60
Total sugars	22.86	16.62	13.71	15.23	14.54	13.52
Total polysaccharides	20.38	14.22	12.30	14.10	13.52	12.46
Total hexose sugar	19.74	14.85	12.25	13.27	12.24	11.70
Hexose polysaccharides	17.64	13.72	11.15	12.41	11.48	10.87
Disaccharides	1.63	0.72	0.73	0.70	0.55	0.59
Hexoses	0.62	0.49	0.45	0.21	0.26	0.30
Total pentoses	2.93	1.68	1.38	1.84	2.17	1.72
Pentoses	0.36	0.34	0.30	0.25	0.15	0.22
Pentosans	2.91	1.33	1.08	1.25	2.02	1.50
Monosaccharides	0.98	0.83	0.75	0.46	0.31	0.52
Monosaccharides to total polysaccharides	.048	.058	.061	.033	.023	.042
Hexoses to hexose polysaccharides	.035	.036	.040	.017	.22	.027
Total pentoses to total sugars	.128	.101	.101	.121	.149	.127

Joints which have been thus starved were found to be capable of rapidly replenishing their food-supply from solutions of dextrose and cane sugar. However, in the sunlight, and even with ample water-supply, the amount of sugar formed by photosynthesis is not enough to equal the consumption, and the joints continue to lose sugar.

Under anaerobic conditions the rate of sugar consumption in *Opuntia* sp. and *O. versicolor* is slightly higher than in air. However, under the former conditions accumulation of certain products of the metabolism soon causes death. Under normal conditions the amount of alcohol formed at any time in the cacti is exceedingly small, increasing apparently with the photolysis of the acids. Alcohol accumulates rapidly in an atmosphere free from oxygen.

THE PENTOSE SUGARS IN PLANT METABOLISM.

This group of sugars, present in varying amounts in almost all plants, constitutes at times more than half of the total sugars of the cacti, not only in the condensed form as pentosans, but it has been found that a not inconsiderable portion of the monosaccharides are pentose sugars. However, the greater proportion are polysaccharides and also form a regular component of the products of hydrolysis of starch grains.

It has, in fact, been observed that leaves of *Parthenocissus vitacea* manufacture starch when placed on solutions of l-arabinose. The nutritive value of the pentoses is still uncertain, but there is little doubt that they are drawn into the respiratory stream, and in the higher plants as well as in fungi and bacteria are of considerable nutritive value.

The mode of formation of this group of sugars has not yet been definitely established, and it is of greatest importance in considering the problems of sugar synthesis in the chlorophyllous leaf. By using the improved methods of analysis it was not possible to confirm the older observations that pentoses accumulate in germinating seeds and in the older portions of plants. In the cacti also no such phenomenon was found. Young joints 3 cm. in length were found to contain about the same percentage or even more pentose than the parent joints. Nor could there be discovered any cases in which old joints (three and four years old) had accumulated larger quantities of easily hydrolyzable pentoses, aside from that contained in the cellulose, which naturally is higher in the older joints. The accumulation of pentoses seems to be a function of the water-content; with ample water available the proportion of pentoses diminishes, while with decreasing water-content these sugars increase. This is especially noticeable in the course of seasonal variation. This is interesting in view of the fact that the mucilaginous material so prevalent in succulent plants is composed largely of pentosans. However, in pure-water solutions at least, these mucilages exert no effect on the evaporation.

Gas Interchange in Mesembryanthemum and other Succulents, by H. M. Richards.

During the progress of a previous investigation on gas interchange and acidity in cacti, some experiments were made and a number of gas samples were taken from various other succulents in their native habitat near the Coastal Laboratory at Carmel. Analyses of the above gas samples indicated that it would be desirable to investigate the CO_2/O_2 relations of these plants more thoroughly. While the number of completed experiments is not large enough to draw definite conclusions, there is a strong indication in the case of all the forms used—*Dudleya*, *Mesembryanthemum*, and *Abronia*—that the carbon-dioxide evolution may be minimal, less indeed than that in cacti. The oxygen absorption, on the other hand, is very considerable.

The work of the summer of 1917 has been to collect a large number of gas samples from these forms under various conditions of temperature and illumination and coincidently to study the acidity conditions of the juices. While most of the experiments were, of course, carried on in darkness, not a few were made in diffuse light or direct sunlight; for, as has been shown, the CO_2/O_2 relations of succulents are highly interesting under illumination, especially in connection with the acidity changes which take place under such conditions. For the purpose

of exposure to sunlight, use was made of the heat-absorbing glass recently developed by D. T. MacDougal. Flasks exposed under a screen of this glass never rose above 31° C. with the highest insolation encountered at Carmel, while the temperature within naked flasks rose as high as 45° C.

Over 200 samples have been collected this summer by the method described in a previous publication[1] and the vials of gas with mercury seal are to be analyzed at later convenience. This method has been shown to be perfectly satisfactory when care is taken to keep the mercury and containers dry. Analyses in 1917 of samples taken in 1913 show no variation from the original determinations. Along with the collection of the gas the necessary acidity determinations have been made.

In addition, a new method of rapid determination of "total acidities" has been devised. For adequate acidity determinations, speed and simplicity are important factors in order to obviate the errors which may arise by the destruction or neutralization of the unstable organic acids due to oxidation or complicated treatment with reagents. It has been found preferable to sacrifice something of sharpness in the end-point of the titrations in order to insure that the acids are, as nearly as possible, in the original condition in which they are in the plants. This new method consists of taking relatively small samples of the tissues to be examined—5 grams or even less—and triturating them thoroughly with clean, washed sand. With care the pulp becomes finely comminuted, is then washed thoroughly, filtered, and made up to a definite volume, of which an aliquot portion may be titrated. Repeated trials have shown that, with careful manipulation, the amount of acid left behind in the rejected tissue is negligible. With the use of a centrifuge this method, which has the advantage of speed and simplicity as well as of thorough extraction, can be carried through very rapidly. Even with ordinary filtration, in most cases the samples may be titrated within 10 minutes from the beginning of the operation.

The analyses of the gas samples, as well as further experiments with live plants, will be completed in New York in the Botanical Laboratories of Barnard College.

Desiccation and Respiration in Succulent Plants, by E. R. Long.

The results of some earlier work showed that when the large globular *Echinocactus* is removed from the soil and dried in the open, stored carbohydrate is formed at a rate exceeding its loss, that a large portion of the increase takes place in the "soluble non-reducing sugar" fraction (including cane sugar), and that in long desiccation, in diffuse light, oxidation of the stored sugars went on at such a rate that the relative dry weight of the plant-tissue remained constant, as large a

[1]Richards, H. M., Acidity and Gas Interchange in Cacti, Carnegie Inst. Wash. Pub. No. 209.

proportion of water being found after six years of desiccation in the case of one plant as was present in the beginning, in spite of a loss of nearly 30 per cent of its original weight by water depletion.[1] These results were very striking, and it seemed that it would be of unusual interest to combine these effects in one plant, thereby obtaining new light on the course of katabolism in the various types of carbohydrate and on the time element involved.

Accordingly, an echinocactus, which had been loaded with carbohydrate by desiccation in the open, after 8 months was placed in a ventilated dark chamber where photosynthesis was no longer possible and katabolism would go on without extensive repair. No. 23 of the series was chosen for this purpose because in treatment, appearance, and amount of water-loss it was comparable to No. 22, a plant desiccated in the open, the analysis of which has been recorded in the following table.

The principal findings embodied in the following table may be briefly set forth as follows: The rate of water-loss tends to become

Results of analyses of Echinocactus.

Analyses made.	No. 23. Desiccated in full sunlight 8 months 10 days and in darkness 22 months 17 days. Total water-loss 57.2 per cent.		No. 7. Desiccated in diffuse light 6 years 1 month. Total water-loss 29.3 per cent.			No. 22. Desiccated in full sunlight 5 months 6 days. Total water-loss 40 per cent.			No. 34. Normal, not desiccated.		
	ab	*a*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
Dry weight per cent of total weight..........	20.2	17.1	9.5	8.0	5.8	14.3	13.3	11.3	5.8	4.2	3.6
Sap (density water = 1.00)	1.018	1.035	1.010	1.018	1.013	1.016	1.027	1.034	1.013	1.011	1.011
Sap acidity, N/10......	0.600	0.400	1.144	0.104	0.148	0.244	0.208	0.156	0.172	0.156	0.128
Total hydrolyzable carbohydrate, per cent of total solids...........	31.5	28.2	22.3	24.2	11.1	44.3	44.2	43.4	32.3	35.7	29.6
Total reducing sugars, per cent of total sap-weight..............	0.08	trace	0.09	0.06	0.04	0.15	0.13	0.10	0.53	0.42	0.10
Total non-reducing sugars, per cent of total sap-weight...........	trace	trace	0.11	0.10	0.06	1.28	1.48	2.67	0.14	0.03	0.05

constant in darkness; the acidity increases in darkness; soluble sugars are broken up, while but little change has taken place in the insoluble polysaccharids. The total hydrolyzable carbohydrate content of No. 23, after its prolonged stay in darkness, is hardly less than that of the normal, No. 34, and is lower than that recorded for No. 22. The high figure for total hydrolyzable carbohydrates in No. 22 is due in a large measure to the high concentration in the pulp of soluble non-reducing

[1] MacDougal, Long and Brown, The End Results of Desiccation and Respiration, Physiological Researches No. 6, Aug. 1915.

sugars, the term "total hydrolyzable carbohydrates," as defined above. covering hydrolyzable carbohydrates of all types, soluble and insoluble. On the other hand, it has been found that the insoluble polysaccharids of this type do break down in the course of long confinement without photosynthesis, but very slowly, and this fact, together with that of the resistance of the echinocacti to desiccation, helps in a large measure to explain the viability of these plants in spite of long starvation.

Relation of the Rate of Root-growth in Seedlings of Prosopis velutina to the Temperature of the Soil, by W. A. Cannon.

In connection with general studies on the behavior of roots in soil, the response of the roots of *Prosopis* seedlings to different soil temperatures was investigated. The experiments were carried on with the use of especially constructed thermostats, by which the soil in which the roots were growing was usually kept within a variation of 0.5° C. The shoots projected into the air, the temperature of which did not usually vary more than 2° C. Observations for the purpose of detecting changes in growth-rate that might occur were continued over periods as long as 93 hours, during which time the rate of growth was observed every 3 hours. The leading results may be summarized as follows:

Growth was observed between 12° C. and 42° C. Growth in this species may possibly occur at soil temperatures below 12° C., and 42° C. probably marks the maximum. The most rapid rate was observed to occur at a soil-temperature about 34° C., at which point a root with an initial length of 16 mm. grew 51 mm. in 12 hours.

The rate of growth of roots in seedling *Prosopis* is not only a condition of the temperature of the soil, but it also is closely correlated with the length of the root. Generally speaking, roots less than 50 mm. in length exhibit, for a limited period, a progressive growth-rate, whereas roots much more than 50 mm. long, either maintain a fairly constant rate or a declining one.

Root-growth of Prosopis velutina and Opuntia versicolor under Conditions of a Small Oxygen-Supply in the Soil, by W. A. Cannon.

The work described below confirms and extends the conclusions and results reported in Year Book No. 15, 1916.

In the earlier work carbon dioxide alone and carbon dioxide with an admixture of atmospheric air were used. In the studies here reported carbon dioxide, commercial oxygen, and commercial nitrogen were employed. The nitrogen-oxygen mixture which was used in many of the experiments was determined by Professor H. M. Richards to be 2.67 per cent oxygen, and from this it was calculated that the nitrogen contained about 0.71 per cent oxygen.

The roots of seedling *Prosopis* exhibit a variable reaction to small amounts of oxygen, depending, apparently, in the main on the length

of the root. In roots that are relatively short, 3 cm. more or less in length, growth goes on for a short time in an apparently normal manner in an atmosphere containing 2.67 per cent oxygen, but in roots which are relatively long—for example, 10 cm.—growth soon ceases in an atmosphere containing this amount of oxygen. On the other hand, growth proceeds in the longer roots for 5 days, more or less, in an atmosphere containing 4.56 per cent oxygen. It seems probable, therefore, that after germination has started in *Prosopis*, root-growth may go on for a considerable period under practically anaerobic conditions. How long this takes place was not accurately determined, but may possibly be related to the duration of the cotyledonary food-supply.

In a soil atmosphere containing carbon dioxide and oxygen the results have been somewhat at variance. It appears, however, that relatively long roots, for example, 20 cm., can grow for at least 24 hours in an atmosphere containing 25 per cent oxygen and 75 per cent carbon dioxide, although growth ceases after this period. Roots approximately 5 cm. in length continue growth in 90 per cent carbon dioxide during administration, although this was not always the case. In all cases where growth stopped, or where the rate was decreased, it was renewed sooner or later after atmospheric air had replaced the gas used. Thus the specific effects of carbon dioxide, even with a large amount of oxygen, are well marked.

In *Opuntia versicolor* growth in all cases stopped promptly in an atmosphere of 2.67 per cent oxygen. Roots 3 to 7 mm. in length stopped growth in an atmosphere containing 4.56 per cent oxygen, although it was seen that roots 11 cm. in length maintained a good growth-rate for 48 hours in the same atmosphere when growth ceased. It appears, therefore, that at least the shorter roots of *Opuntia* cuttings have a greater oxygen requirement than the longer roots of *Prosopis* seedlings, but that a differential result also occurs. It remains to be seen whether the latter is associated with the well-known differential development of the roots of the species into shallow absorbing and more deeply placed anchoring roots, as appears to be indicated, although this is suggested.

Rate and Course of Growth of Succulents, by D. T. MacDougal.

The construction of a dozen auxographs of improved pattern (see Ann. Report, Dept. Bot. Research for 1916, p. 57, Carnegie Inst. Wash. Year Book) has made it possible to secure an amount of information upon which some important conceptions of growth may be based. The annotated records of growth now available at the Desert Laboratory probably comprise more than half the existing information on the subject. The changes in length of an individual joint of an *Opuntia* for 16 months are included in the data available. Measurements of growth of the massive succulents was continued with *Echino-*

cactus and *Carnegiea*, and with the smaller *Mesembryanthemum*. Determinations of the acidity of the sap of this plant show that while the total range is not as great as that found by Richards in *Opuntia versicolor* (Acidity and Gas Interchange in Cacti, Carnegie Inst. Wash. Pub. No. 209, 1915), yet the daily course of variation is marked.

The leaves are triangular in cross-section, and as the pairs emerge from the sheathing bases of the antecedent pair the inner or upper faces are appressed. The upright position implied is held until a half or a third of their length is attained. The tips of a pair were harnessed together and, being turgid and firm, were arranged to press upward on the bearing lever of the auxograph.

The general features of the daily behavior of this plant were quite similar to those of *Opuntia* in that elongation accelerated in mid-forenoon, about 9 to 11 a. m., and continued until 1 to 3 p. m., when it was checked and a shrinkage ensued which generally ended at 5 or 6 p. m. or sunset. After this time, temperature being favorable, a low rate of growth continued through the night and until the daily acceleration occurred a few hours after sunrise.

The daily course of transpiration has not been determined, but it is allowable to assume that the imbibition capacity of the growing regions is lessened by acidity, as it is in *Opuntia*.

The results of measurements of growth of the apical part of the globular *Echinocactus* and of the cylindrical *Carnegiea* afford some interesting comparisons, since both are massive succulents, but present a type of respiration somewhat different from that of *Opuntia* and *Mesembryanthemum*.

The spines of *Echinocactus* arise from special meristem tracts lateral to the growing-point, and as the growth is wholly basal the rigid tips afford an excellent bearing for an auxograph arm. A preparation was kept under observation at a point some distance from the walls of a greenhouse late in April 1916. Temperatures of the body near the surface were taken by a thermometer with a thin bulb left in place during the course of the observation. Growth began at 22° C. to 24° C. about 8 a. m., continuing during the warm daylight period and until nearly 8 p. m. Nothing higher than 37° C. was shown by the body. The daily rate varied from zero to 0.05 mm. per hour and no retractions were discernible. The length remained fairly constant when growth ceased. The temperature of the body of this plant did not fall below about 14° C. during any part of the period.

The same plant was available for experimental purposes in March 1916. The cluster of spines, the tips of which had emerged for a length of 4 to 6 mm. in 1916, began to show freshly colored sections at their bases indicative of elongation, and one of these was brought into bearing in the cup-shaped end of the vertical arm of an auxograph. The preparation was placed near the south end of an unheated glass-house,

with the result that the temperature of the body fell as low as 4° C. at 7 a. m. and reached a point at which growth ceased at about 8 p. m. The steadily decreasing temperature was accompanied by a shrinkage—due in all probability to lessened imbibition capacity as a result of low temperature. Resumption of growth took place in the forenoon at temperatures about identical with those of the previous year. The total daily growth amounted to as much as 1.25 mm. to 1.5 mm. daily, all of which was made between 9 a. m. and 8 p. m.

The record of growth of *Carnegiea* included measurements of the variations in the length of the spine as well as of coincident readings of the swelling of the apical region of the stem near the base of the spine. Elongation of the spine on daily rising temperatures began at temperatures of 24° C., 18° C., 18° C., 15° C., 13° C., and 13° C. on separate days and was very active at 32° C. A period of continuous elongation of the spine was comprised between April 10 and 17, 1916, during which time the air-temperature ranged between 14° C. and 28° C. The temperature of the body coincided with the lower night temperature of the air and did not rise above 32° C.

The maximum enlargement of the spine was at the rate of 0.075 mm. per hour, while that of the neighboring apical tract was not more than a third of this rate. After the spine had reached nearly mature length the apical tissue accelerated, showing a rate as 0.088 mm. per hour. Growth began on rising temperatures of 15° C. and above and was observed at 40° C. of the body. The main part of the growth took place in the daytime and no action directly attributable to light effects could be detected.

Echinocactus and *Carnegiea* are active during the period in which the temperature is within the tonic range, as taken from thermometers inserted in the tissues. This implies that such plants grow during the daylight period in the open and as far into the night as the temperature permits, the maximum rate being attained during midday. Numerous tests show but little variation in the acidity of *Echinocactus* and *Carnegiea* and it is to be inferred that the cessation of growth and shrinkage are purely temperature and transpiration effects, as the acidity does not vary widely enough to modify the imbibition and growth capacity of the cells as in *Opuntia* and other "sour" plants.

Growth of Wheat (Triticum) and Corn (Zea), by D. T. MacDougal.

Most of the data concerning the rate and course of growth of these two important crop-plants have been obtained chiefly by the measurement of numbers of organs for a brief period. The facts of importance in connection with the present paper have been obtained by analyses of the march of growth from day to day. For example, the growth of a single leaf was followed from March 19 to April 1, and the changes in length of a leaf of corn from April 8 to April 22.

Varieties of these two plants cultivated in the region of the Desert Laboratory were selected, and grains were germinated in an unheated glass-house. The bases of the plantlets were fixed in place by layers of plaster poured on the surface of the soil. The tips of leaves which had emerged to a length of 10 to 15 mm. were brought into the field of a horizontal microscope and the variation in length measured at half-hour intervals so far as it was possible to do so. The leaves were maintained in a vertical position by a requisite number of horizontal glass rods with a minimum of shading effect. The increments measured are of course inclusive of the elongation of the base of the leaf and of the internode from which it arises, as well as of any residual action of internodes.

Retardation of growth of *Zea* and *Triticum* occurs at more than one place in the temperature scale and at different times of the day. An uneven rate of elongation was particularly noticeable in *Triticum*, although displayed by *Zea* as well. It was thought that the irregularity might be due to a sagging of the leaf-blade which would cause its tip to move with a varying rate across the field. Similar leaves attached to the bearing arm of an auxograph under a stretching tension traced an undulating line indicative of similar irregularities. Cessation of growth, especially in some of the instances in *Zea*, may be reasonably attributed to a direct temperature effect, especially in the cases in which the thermometer stood at 30° C. to 35° C. for extended periods. In the greater number of instances, particularly in *Triticum*, no such explanation could be deemed adequate, and the matter is referred to varying imbibition capacity coincident with variations of acidity due to respiration modified by various agencies.

The highest rate that was maintained for some time by *Zea* was found to lie between 27° C. and 30° C. It is not possible to fix upon any limits of temperature within which growth might be continuous in this plant. It is obvious that "secondary" maxima might readily be derived from data of this character.

No retardations occurred except after 11 a. m. in either *Zea* or *Triticum*, and while *Zea* showed an acceleration late in the day after retardation at high temperatures, *Triticum* did not. The retardations in question are relatively least in the earlier stages of development, when the joints are not more than one-fourth or one-fifth adult size and have the effect of a flattening of the curve that is of slowing-down growth. The action becomes more pronounced until a stage is reached when more and more of the elongation of the forenoon is retracted in the afternoon. The tonic range of the two plants is of course not identical. Wheat grows at a lower range than corn and probably reaches its upper limit near the figures given.

There are but three allowable causes in the present state of our knowledge, to which might be attributed the slackening or inhibition

of growth or actual shrinkage of growing joints after midday and continuing until the following morning. These are destruction of enzymes concerned in renewing building material, excessive transpiration by which a plant might lose bulk by water-loss, and accumulation of acids or other respiration products which would clog metabolism and reduce the water-holding capacity of the protoplasm. There is evidence available showing that the second and third conditions may operate to check, cancel, or retract growth-elongations.

Measurement of Light in Physiological Aspects, by D. T. MacDougal and H. A. Spoehr.

Experimentation with the direct and indirect effects of light on organisms requires sources of light under good control, screens for transmitting special regions of the spectrums, and methods of measurement of the relative intensity of the illumination falling on the organism.

Sunlight may serve in some work when the requisite screens are available, but incandescent filaments, mercury, and amalgam vapor arcs inclosed in glass or in quartz may be used as sources of light down to wave-lengths of 0.28 μ. A series of formulæ for a number of glasses which would transmit various parts of the spectrum has been developed in the laboratory of a prominent firm of glass-makers, of which the following promise the greatest usefulness:

Red: High transmission in red removes all light below 0.61 μ.
Blue: Transmits only blue below 0.52 μ and may be made deeper to transmit only below 0.50 μ.
Yellow: High transmission in red and infra-red and through green to 0.48 μ giving about 75 per cent of incident white light. All ultra-violet absorbed.
Uviol: Transparent to visible spectrum, transmitting ultra-violet to 0.31 μ in sheets 0.25 inch thick, to 30 μ through 0.125 inch thick.
Heat-absorbing: Absorbs most of infra-red and 97 per cent of heat of Nernst lamp; gives a pyrheliometer reading about half that of good window-glass. Transmits 65 per cent of incident white light.

The blue-violet region of the spectrum is of the greatest interest to the biologist, and as photometers, thermopiles, and pyrheliometers do not register the dissociation effects, it is proposed to use the photo-electric cell as developed by Elster and Geitel and by Dr. Jacob Kunz. This instrument has the great advantages of extreme sensitiveness in the blue-violet region and ease of manipulation; it records immediate and directly proportional values, and can be used for extensive ranges of intensities.

A comparison of the results to be obtained by the use of two methods is afforded by the data given below. Direct sunlight at the Desert Laboratory is taken as 100, and the figures in both cases are percentages of this total. The values from the pyrheliometer were calculated in calories per square centimeter per minute, and those of the sodium photo-electric cell are from readings of the high-sensitivity galvanometer.

Illumination.	Proportion of direct sunlight (sunlight = 1.39 calories per sq. cm. per minute).	
	Smithsonian pyrheliometer values.	Sodium cell values.
	p. ct.	*p. ct.*
Direct sunlight	100	100
Transmission—		
Uviol glass	90.2	86.6
Yellow glass	53.6	5.1
Red glass	42.4	0.62
Heat-absorbing glass	25.4	63.2
Blue glass	10.5	49.0

The sodium cell connected with a suitable portable galvanometer offers many advantages for measurement of light intensities in natural habitats. It seems highly probable that more exact measurements in the blue-violet region, so important in photolysis and phototropism, will yield information by which some of the current discordant results may be harmonized. In any case, the action of the photo-electric cell in light is more nearly parallel to that of the organism than that of any other light-measuring instruments hitherto available. (Science, n. s., vol. XLV, No. 1172, pp. 616–618, June 15, 1917.)

ECOLOGY AND PHYTOGEOGRAPHY.

Osmotic Concentration of Tissue Fluids in relation to Geographical Distribution, by J. Arthur Harris.

Cryoscopic studies at the Desert Laboratory in 1914 (Carnegie Inst. Wash. Year Book, 1915, p. 81, and 1916, p. 79) confirmed the conclusions of Drabble and of Drabble and Fitting by showing that the osmotic concentration of the sap of plants may differ in the local habitats of a region. Since then these studies have been extended to a number of very diverse areas. At present, the ultimate object of these investigations is the completion of a reconnaissance of the sap properties of the vegetations of typical phytogeographical regions. The regions in which fairly comprehensive series of observations have been made are the following:

1. Southwestern deserts in the neighborhood of the Desert Laboratory, which have been studied in both winter and summer growing-seasons. Studies in the winter have of necessity been limited to the desert floor. Those made in the summer have ranged from the Laboratory domain through all the remarkable transitions of environmental conditions and vegetation to the summit of the Santa Catalina Mountains.
2. The coastal deserts of the island of Jamaica.
3. The mesophytic region about the Station for Experimental Evolution, Long Island, New York.
4. The pineland and Everglades hammocks of southern Florida.
5. The montane rain forest of the Blue Mountains of Jamaica.

6. The marine marshes of the Atlantic coast in the neighborhood of New York and along the east coast of Florida.
7. Mangrove swamps on the coast of Jamaica, and from Cape Florida to about the northern limit of the species in the Indian River region.
8. Strand vegetation on the Atlantic Coast, in the latitude of New York and along the Florida coast.
9. Preliminary studies on the Florida keys.
10. The Everglades, Florida.

During the year an account of the montane rain forest of Jamaica has been published (Amer. Jour. Bot., vol. IV, pp. 268–298), the mangrove swamps have been treated in a preliminary way (Biol. Bull., vol. XXXII, pp. 202–211), and a general account of the work given (Science, n. s., vol. XLVI, pp. 25–30).

Two months have been spent in southern Florida and on the Indian River, with the assistance of Mr. Charles W. Crane, in field work.

Rate of Growth in relation to Altitudinal Conditions, by Forrest Shreve.

Work was begun several years ago with a view to ascertaining the extent to which the rate of growth and density of stand of the yellow pine are influenced by the dissimilar conditions of different altitudes. This work has been prosecuted mainly on the Santa Catalina Mountains, in the vicinity of the stations at which climatological records have been secured. Some of the more general results of the work have been elaborated and prepared for publication.

The number of pine trees more than 10 cm. in diameter increases with altitude from 6,000 to 9,000 feet, as enumerated for areas of the same size. These elevations are near the lower and upper limits for the distribution of this tree. The total stump area and total volume of the adult trees increases still more sharply with altitude. The actual number of trees at 6,000 feet is slightly greater than at 7,000 feet, but the number at the former elevation is largely made up of very young individuals. The rate of growth was determined by ring count and diameter measurement of selected trees of all sizes and all types of crown. A comparison of the curves for rate of growth at 6,000, 7,000, 8,000, and 9,000 feet on south-facing slopes and for 6,000 and 7,000 feet on north-facing slopes shows a remarkable similarity in all cases except the 9,000-foot area, where the rate was much higher than at lower elevations. Through the vertical range of the yellow pine in the Santa Catalina Mountains there is a sharp gradient of change in all of the leading climatic conditions. That these changes should be without influence on the growth of the dominant tree of these elevations can be explained only on the possibility that there is a compensating operation of the conditions. The increase of rainfall from 6,000 to 8,000 feet (and in most years to 9,000 feet) favors increased growth, but the decrease in the length of the frostless season on ascending through these altitudes is calculated to lessen the total

seasonal growth. It appears possible that these opposing influences operate in such a manner as to give the end-result of nearly equal growth at different altitudes. Such a relative uniformity of growth-rate would not contradict the probability, for which there is some strong evidence, that the lower limit of the yellow pine is determined by deficiency of soil-moisture, together with high evaporation, and its upper limit by the length of the frostless season.

Rainfall Conditions of Desert Mountains, by Forrest Shreve.

The measurement of summer rainfall on the Santa Catalina Mountains has been carried on at three stations since 1907 and at seven stations, at 1,000-foot intervals, since 1911. The published results of the earlier readings, together with those more recently secured, have brought out four features of general interest:

1. The gradient of increase of rainfall on a relatively abrupt mountain side is much steeper than it is on a gently rising stretch of country, such as that occupied by stations of the Weather Bureau in Arizona, with which comparisons have been made.
2. There is a very sharp rise in the rainfall between the base of the Santa Catalina Mountains, at 3,000 feet, and the station at 4,000 feet, a feature believed to be true of the lowest interval of 1,000 feet on all mountains in the southwestern deserts, regardless of their basal altitude.
3. There is another sharp rise in the gradient of increase at the elevation at which heavy forest is first encountered.
4. In certain years the rainfall has been less at 9,000 feet than at 8,000 feet.

The emergence of these facts has made it seem desirable to continue the readings at the same stations and to establish others for comparison. For the summer of 1917 a new series of accumulative rain gages was installed, embodying the same features as the gages previously used, in which kerosene is employed to prevent evaporation, and the readings are made by volume, with reduction by the area of the funnel. A new series of stations was located on the south face of the Pinaleno Mountains, in Graham County, Arizona. This range was selected because it has a greater basal altitude than the Santa Catalinas and a greater maximum altitude, and because the lower limit of forest is nearer the base and farther from the summit—in terms of vertical distance—than in the Santa Catalinas. It will be possible, therefore, to test out all of the above conclusions by possessing parallel series of data for the two mountains. It will be of particular interest to see if the Pinaleno Mountains exhibit a sharp rise of rainfall with the first occurrence of forest and whether the increase of rainfall with altitude is reversed at the 10,000-foot station, as is suggested by the occasional reversal at 9,000 feet on the Santa Catalinas.

Evaluation of the Temperature of the Soil as an Environmental Factor, by W. A. Cannon.

Hitherto emphasis has been placed on the temperature of the air, to the exclusion of that of the soil, whenever temperature as a factor in the distribution of species of plants is referred to. This practice results from the lack of data both as to the temperature of the soil and as to the reaction of a plant to soil-temperature; but with such series of data in hand, not only can the importance of the temperature of the soil as one element in the environmental complex be measured, but such evaluation might aid in determining what species might be expected to survive under given conditions of soil-temperature and thus be of economic importance. The relative importance of the temperature of the soil in plant distribution can be sufficiently illustrated by a single example.

°C.	mm.
15	0.10
20	0.2
25	0.4
30	0.5
32	1 to 6

One of the most striking species of plants in southern Arizona is *Covillea tridentata*. Seedlings of the species were grown at the experimental plot of the Coastal Laboratory to see what the plants would do in such a comparatively humid and equable climate, where relatively low temperatures prevail most of the year, but where killing frosts rarely occur. The seedlings made little growth and did not survive. The leading apparent reason for this is to be sought in the root-temperature relations of the species, as an effective growth-rate of the roots of *Covillea* occurs only in fairly warm soil. The accompanying table gives the approximate hourly rate of root-growth of *Covillea* as determined by preliminary laboratory experiments.

The number of hours during which the soil was at the temperatures 15° C., 30° C., and 32° C. at the Desert Laboratory and at the Coastal Laboratory at a depth of 30 cm. and for the month of August is presented in the accompanying table.

	15° C.	30° C.	32° C.
Carmel, hours.	744	0	0
Tucson, hours.	0	547	197

With the known growth-rate of the roots at the temperatures given immediately above, the expected total root-growth of *Covillea* at Carmel and at Tucson would be as follows:

Place.	Hours.	°C.	Root-growth.
			mm.
Carmel.......	744	15	74.4
Tucson.......	547	30	273.5
Tucson.. ..	197	32	315.2

Therefore, the total expected root-growth of *Covillea* during August at Tucson would be 588.7 mm. as opposed to 74.4 mm. at Carmel. By denominating the temperature of the soil as t and the hourly rate as r, the biological significance of any summation of soil-temperatures, tr, can be numerically presented, as in the foregoing table; and with sufficient data on the temperature of the soil the tr could be plotted and the ecological importance of the soil-temperature relation be graphically expressed. An additional method of representing the relative efficiency of different situations for any species consists in a comparison of the tr for any temperature with the maximum tr for the stations. For example, Carmel and Tucson may be chosen and the data as above presented may be used. If every hour of the month of August were at the optimum soil-temperature for *Covillea*, for example, the expected root-growth would be 1,190 mm. It is thus to be seen that at Carmel in August under actual conditions the expected root-growth of *Covillea* can not be over one-sixteenth that at optimal soil-temperatures, while at Tucson the total root-growth would be approximately half that possible. Therefore it can be said that the soil-temperature at a depth of 30 cm. at Tucson is approximately 8 times as effective for root-growth of *Covillea* as the temperature of the soil at the same depth at Carmel, a difference so great as to account for the survival of the species in the one locality and its failure in the other.

Plant Distribution on Desert Mountains, by Forrest Shreve.

In connection with the comparative study of physical conditions on the isolated mountain ranges of southern Arizona, opportunities have been made for a further examination of their vegetation, both with respect to its character and its vertical limits. Data are also being accumulated with an ultimate view to a comparison of the floras of the forested portions of some of the large mountains. During the past year visits have been made to the Santa Catalina, Pinaleno, Santa Rita, Huachuca, and Whetstone mountains. Particular attention has been given to detecting the plants which are common components of the vegetation in the Pinaleno and Huachuca mountains but are not known to occur in the Santa Catalinas. The former of these ranges is 1,500 feet higher than the Santa Catalinas and consequently presents a large area in which the physical conditions are unlike those of any portion of the latter mountain. The extensive forest of *Picea engelmanni* above 9,800 feet on the Pinaleno range and the small but well-developed meadows and alpine parks afford habitats for a considerable number of species which have not been found in the Santa Catalinas. At lower elevations are also to be found a few species which do not occur in the more isolated mountains, although appropriate altitudes and similar conditions would appear to favor their invasion. The Huachuca Mountains are well known to have a rich flora, comprising

a score or more of plants that have not been seen elsewhere in the United States, although some of them are common to the Sierra Madre Occidental of Mexico. A few of these forms are conspicuous elements in the vegetation of the Huachucas. In this range are also to be found a number of species of high-mountain plants common to northern New Mexico and Colorado, which do not occur in the Santa Catalinas.

The history of the distributional movements of plants among the isolated mountains of the southwest has been controlled by the mobility of the plants themselves and by the physical conditions which their invasions have encountered. A few cases have been discovered in the Santa Catalinas which appear to represent early stages in the invasion of these mountains by plants which are widespread in adjacent ones. The principal evidence for this is the fact that they are now occupying only an extremely small part of the terrain which is favorable to them and that they show no tendency to localized occurrence in the adjacent mountains. Among these are *Abies arizonica, Populus angustifolia, Vaccinium scoparium, Cerasus crenulata,* and *Parthenocissus vitacea.*

During the summer of 1916 the seeds of 14 species of plants from the Pinaleno and Huachuca mountains were planted at favorable altitudes and in favorable habitats in the Santa Catalinas. No report can yet be made on their fate and repeated plantings may be necessary to secure conclusive results as to their ability to germinate, survive, and spread under conditions so nearly identical with those in which they occur only 60 and 80 miles away. If any of these species become established it will indicate that their previous absence was due to their immobility; however, this may have been due to different conditions. Their behavior will be watched with care, as throwing light on the manner in which natural introductions have previously taken place.

Vital Statistics of Desert Plants, by Forrest Shreve.

A record of the germinations, and the fate of seedlings, of several species of desert perennials was begun on an observational area near the Desert Laboratory in 1910 (see Year Book for 1912, p. 58). This record now extends through seven years and some of its features have reached such a point that they have been described for publication.

On the area of 557 square meters no germinations of the giant cactus (*Carnegiea gigantea*) have been detected in eight successive summers. A single seedling found in 1910 is still surviving; it has had an average growth-rate of 5 mm. per annum during the past four years and has reached a height of 35 mm. These measurements, and others on plants of similar size, indicate the extremely slow rate of growth in seedlings of *Carnegiea.* The curve of acceleration in growth with increase of size was worked out several years ago and indicates that the largest individuals of this cactus are from 125 to 175 years of age. Vigorous half-grown plants exhibit a maximum growth of 100 mm.

per annum under the most favorable conditions. No germinations of the barrel cactus (*Echinocactus wislizeni*) have been observed on the area, and only one seedling was found on the establishment of observations. During the past four years this seedling has grown 70 mm. in height and 60 mm. in diameter, reaching a height of 110 mm. The evidence with respect to these two massive succulents, both on this observational area and on other areas that have been less thoroughly studied, is that they produce very few seedlings and that a relatively high percentage of them survive and reach mature size.

The number of germinations of palo verde (*Parkinsonia microphylla*) has been extremely variable, ranging from none in 1915 to 542 in 1910. This is due to the fact that seed crops are borne only in very favorable years and that the waxy coating of the fresh seed delays its germination from one to several years. The early years of work on this area demonstrated that the rate of mortality of the seedlings of palo verde is determined by soil-moisture conditions and not by competition with each other nor with other vegetation. Germinations take place only in the summer rainy period, and the number of deaths among the seedlings of a given year is very great during the arid season immediately following. The mortality continues to be high for two or three years, at the end of which time the population has usually been reduced to a low percentage of the original number of germinations. In 1917 there survive only 2 of the 542 individuals which germinated in 1910, and only 5 of the 29 that germinated in 1916. The total number of germinations in the seven summers of observation has been 1,198, and the number of survivals is 19.

The seeds of ocotillo (*Fouquieria splendens*) are produced in great profusion and the number of seedlings that appear with the first rains of summer is so great that it is impracticable to keep a record of them. The arid after-summer causes the death of all but an extremely small number of these seedlings. The record of the survivors has been begun in their second year. The total number of ocotillo seedlings surviving into the second summer has been 21, while 5 were found on the commencement of observations. In the summer of 1917 there were 7 of these 26 surviving, which is probably a representation of 1 for each 50,000 to 100,000 germinations for the seven years.

The extremely slow rates of growth of desert perennials have been familiar for some time. It appears from the observations just described that the establishment of new individuals in the plant populations of the desert is also an extremely slow process, even for plants which are as abundant and characteristic as those that have been used. The low rate of establishment, slowness of growth, and attainment of great longevity combine to give desert vegetation a conservatism of change which is in keeping with the adverse conditions under which it lives and is in sharp contrast to the very rapid development and

extremely abundant representation of the annual species which appear only during the periods of favorable moisture conditions.

The Role of Climatic Conditions in determining the Distribution of Vegetation in the United States, by Burton E. Livingston and Forrest Shreve.

The character of this investigation was described in the Year Book for 1916 and the advanced state of its prosecution was mentioned. The large body of data which has been brought together, showing the extreme values for 38 climatic conditions in 115 distributional areas, has been found to merit in itself a fuller examination and comparison than was at first expected. A graphic method which has been devised for the presentation of the climatic extremes has been found to facilitate the study of these data and to furnish evidence as to which of the climatic conditions are of greatest weight in determining particular cases of distribution. The major conclusions of the work have not been altered under further testing of their validity, and other conclusions have been greatly amplified. The final stages of the investigation have shown still more conclusively that the principal types of vegetation in the United States are controlled in their distribution by those moisture conditions which have most to do with the maintenance of an equilibrium between absorption and transpiration in individual plants.

GENETICS AND TAXONOMY.

Experimental Evolution in a Desert Habitat, by W. L. Tower.

The analysis of the composition of the mutants arising from the series C. H. 15.7 and C. H. 156.8 and the extensive and final testing of the adaptation of introduced stocks to desert conditions have occupied the major portion of my attention since the last report.

ADAPTATION OF INTRODUCED SPECIES.

Any desert environic complex represents probably the most variable and diversified set of conditions that organisms have to meet. The inhabitants, plant and animal, in any desert have come from progenitors that originated in more moist conditions.

In the study of introductions of species from moist into desert environments, two problems are ever before one—the adjustments necessary to survival and the adjustments necessary to reproduction.

On introduction it is necessary to aid artificially the reproductive process, as none of the introduced species could breed without some degree of aid in meeting the conditions of the desert. This aid in reproduction can be regarded as a step from the moist towards the full natural rigors of the chosen desert environment.

ADJUSTMENTS NECESSARY TO SURVIVAL.

The cultures of introduced species now at Tucson were subjected to rather severe tests in the year 1917, with the result that they show, after six generations of living in the desert complex, quite perfect adjustment to the survival end of the problems that they have to encounter. In the earlier generations after introduction, in the dry fore-summer, as soon as the temperature reaches the point at which they would normally emerge for reproduction, they will do so regardless of whether the moisture conditions are favorable or not. After the sixth, or at the latest the eighth generation, none emerge until the water-relation has also attained the requisite concentration. Thus in the dry fore-summer of 1917 in no cultures older than F_8 did any emerge, although they were easily brought from the soil by the addition of water. Under F_6 they were found to emerge in proportion to the number of generations they had lived in the complex.

The cultures that showed adequate adjustment and did not emerge until the total complex was normal for reproduction also showed the highest capacity for retaining water against any desiccating activities. It is certain, therefore, that complete adaptation, gradually attained, and in directions induced by the environment, has been attained in these cultures.

ADJUSTMENTS NECESSARY TO REPRODUCTION.

It is not certain that any changes that are the product of the introduction have taken place in matters that affect reproduction. None of them will reproduce without a fairly high water-content in the medium and in the food—that is, water in very considerable amounts must be available. In the dry fore-summer of 1917 a growth of *Solanum eleagnifolium* was attained, then deprived of water of irrigation, so that the plant had a low water-content, and upon this T.99, the most fully adjusted stock, was placed, but refused to breed and finally returned into hibernation, while a second culture of T.99, in which water was given to the food by irrigation, did breed, showing clearly that available water in the medium is necessary for reproductive activities.

MUTATING STEM STOCKS.

The two chief series, C.H.15.7 and C.H.156.8, continue to breed true to type and behavior, as noted in previous reports.

The main effort of the year with these experiments has been the study of the composition and nature of the different mutants. As previously noted, these are either (1) recombinations, or (2) recombinations with alterations.

During the past year genetic data regarding the nature and behavior of six of the "recombinations" has been completed, *i. e.:*

Mutant "melanothorax": body form, multitæniata; dorsal pattern, melanothorax; ventral pattern, multitæniata; juvenile characters, decemlineata.
Mutant "obscura": body form, decemlineata; dorsal pattern, melanothorax, less certain elements; ventral pattern, decemlineata; body color, decemlineata; juvenile characters, decemlineata.
Mutant "white multitæniata": body form, multitæniata; pattern, multitæniata; juvenile characters, decemlineata; body color, ivory white, recessive.
Mutant "dark multitæniata": body form, multitæniata; pattern, multitæniata; juvenile characters, multitæniata; body color, dark, diffuse yellow dominant; new.
Mutant "dark multilineata": body form, multilineata; pattern, decemlineata; juvenile characters, multitæniata; body color, dark, diffuse yellow-brown dominant.

In these there are recovered in the mutants in recombinations the following "characters" or groups of characters, which, however, are acting in these mutants as units:

Body form: multitæniata, decemlineata, multilineata which was present in the original multitæniata stock.
Pattern: decemlineata, multitæniata, melanothorax, and obscura.
Body color: decemlineata, multitæniata, ivory white, a new recessive condition, dark diffuse yellow brown, a new dominant condition, an intensification of the condition in the typical multitæniata parent.
Juvenile: decemlineata, multitæniata.

None of these "characters" is expressed in the form seen in the mutants in the stem stock, which is a combination of all. In the mutants, however, the characteristics come out with the purity indicated. Each of these mutants breeds true in inbred lines without limit, whether as pairs or population cultures.

Thus far these recombination mutants involve the recombination of what might be characterized as "huge blocks" from the original parental organizations. From other work with these same species it is known that the "blocks" shown in these recombinations which behave as units are capable of being broken into many lesser units of activity and behavior in crossing.

A point of considerable interest, possibly of much significance, is that it is always the "recombination mutants" that are the first to appear after the initiation of the mutation process in the stem stock. Later these mutants and (later still) the stem stock throw off the second group of mutants, those due to breaking-up and rearrangement of the characteristics that entered into the stem form. The second group of mutants, in the main, behave as a multiple allelomorph, and are extremely complex in composition and in behavior; consequently their behavior and genetic composition have not been fully made out.

A mutating stock of this kind, breeding freely in nature, producing in every generation the recombination mutants and the alteration type of mutant, would offer an almost endless series of possibilities for the production of a long series of types differing in aspect yet on the whole having the same generic basis. Were this coupled with wide dispersal, differing habitats, and the consequent possibilities of ecological adjustment and survival, it would seem to include all the necessary conditions

for the production of a generic group, or at the least for a widely dispersed, closely related group of "species" in nature.

Report on Cactus Investigation, by N. L. Britton and J. N. Rose.

Subsequent to the closing at the end of 1916 of the five-year period devoted to field, greenhouse, and herbarium investigation, Dr. J. N. Rose, Research Associate during that period, returned to the United States National Museum, but by permission of that institution has given all his time to the preparation of manuscript for the monograph of the Cactaceæ, in cooperation with Dr. N. L. Britton, director-in-chief of the New York Botanical Garden. This monograph has been rendered much more complete than was otherwise possible by large collections obtained by Dr. J. A. Shafer last winter in Argentina, Paraguay, and Bolivia, thus furnishing much valuable material for illustration and adding greatly to our knowledge of the cactuses of South America. Dr. Britton commissioned Dr. Shafer for this work.

Analysis of a Potato Hybrid, Solanum fendleri × S. tuberosum ("Salinas"), by D. T. MacDougal.

The wild potato of Arizona, *S. fendleri*, which is to be found on the mountains above 5,000 feet, produces a small tuber and endures the extremes of the climate of that region. It has been carried through the acclimatization cultures at Tucson and at the Coastal Laboratory. Flowers were finally produced at Carmel in 1913 and 1914, at the time the domestic variety of that region was in bloom. A cross was obtained in 1914 and the second generation, represented by about 1,000 plants, was brought to maturity in 1917. The first generation is intermediate between the two parents and produces tubers about two or three times as large as the wild parent. A lineal series of these tubers will be cultivated in order to test the matter of vegetative mutation. The second crop in this line has already matured.

The F_2, or second generation, includes a number of individuals which appear to be identical with the wild parent. Whether the domestic parent is similarly represented can not be definitely ascertained for another season. Many recognizable qualities of both parents are represented in a large number of intermediate forms.

Professor G. H. Shull, of Princeton University, has undertaken a genetic analysis of the domestic parent, with preliminary results which indicate its hybrid constitution very clearly.

The cultures of the hybrid in 1917 include lots of plants grown on the Santa Catalina Mountains, Arizona; at the Citrus Experiment Station, Riverside, California; Desert Laboratory, Tucson, Arizona; the Coastal Laboratory, Carmel, California; a ranch at 1,000 feet elevation a few miles from Carmel, and on the testing-grounds of the Department of Plant Breeding of the University of California, Berkeley, California.

DEPARTMENT OF EMBRYOLOGY.*

FRANKLIN P. MALL, DIRECTOR.

The facilities of the Department were materially increased by the acquisition, in October 1916, of additional floor space in the new Hunterian Laboratory, erected by the Johns Hopkins University adjacent to the present Anatomical Laboratory. The building is of fireproof construction, and one floor of it, consisting of over 6,000 square feet, was especially designed for the purposes of this Department. In addition to four large rooms, which are used respectively as library, room for microscopical technique, machine shop, and modeling room, there are ten smaller rooms for investigators and assistants, a basement room, three dark rooms, and a commodious vault for the preservation of valuable specimens and records. The rooms are well equipped with instruments, glassware, and optical apparatus suitable for embryological investigation. Parts of the larger photographic apparatus were constructed in this country especially for our work.

After securing these new quarters the space previously occupied by the Department in the Phipps Clinic was relinquished. I take advantage of this opportunity to express our obligations to Professor Adolf Meyer, of the Phipps Psychiatric Clinic, and to Dr. Winford H. Smith, superintendent of the Johns Hopkins Hospital, for their cooperation in providing us with temporary shelter.

Since my last report the following persons have been added to the staff or have undertaken work independently in connection with the Laboratory:

Last autumn Dr. Adolf H. Schultz, of Zurich, became a member of our staff to continue the work of Dr. Reicher, who returned to Russia at the beginning of the war. Like Dr. Reicher, Dr. Schultz has been trained by Professor Schlaginhaufen, and is therefore well qualified for the study of the human embryo from an anthropological standpoint. For the past year and a half Professor Kunitomo, professor of anatomy at the Medical School of Nagasaki, who is abroad at the direction of the Government of Japan, has been here investigating the development of the spinal cord and cauda equina in human embryos. He is now preparing his studies for publication. In May 1917, Dr. Arthur Meyer, professor of anatomy at Leland Stanford Junior University, began work upon normal and pathological embryology in collaboration with me. Professor Meyer is on leave from his university for a year and a half and while with us will rank as Research Associate. On September 1 Miss Jane H. Ross assumed her duties as Research Assistant. Dr. Theodora Wheeler has been studying certain specimens

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in our collection and her preliminary report on a spina bifida monster has been published. The completed paper will soon appear in the Contributions to Embryology, vol. VII. Dr. Abram Kerr, professor of anatomy at Cornell University, spent this spring at the Laboratory, completing a study of the brachial plexus. Dr. J. Whitridge Williams, Dean of the Johns Hopkins Medical School, is collaborating with me in a study of human implantation, our collection being especially rich in suitable specimens for such researches. Dr. Edmund V. Cowdry, professor-elect at the Peking Union Medical College, China, will continue his work on mitochondria during the coming year. Professor G. W. Bartelmez, of the University of Chicago, was with us in September of last year, preparing for publication a study of human embryos less than 2 mm. long, in collaboration with Professor H. M. Evans. A preliminary report of this work has been published.

The following investigators have been with us for shorter periods: Professor B. F. Kingsbury, of Cornell University; Professor H. D. Senior, New York University; Dr. F. P. Reagan, Princeton University; Mr. E. H. Norris, University of Minnesota; Dr. Robert Chambers, Cornell University; and Miss Marion Hines, of the University of Chicago.

The collection was used also by Dr. Edwin G. Davis for the study of the early development of the ureter, in collaboration with Professor Hugh H. Young, director of the James Buchanan Brady Urological Institute.

Several circulars of appeal for laboratory specimens have been issued during the year to the medical profession. One of these described the department; another, the classification and preservation of the specimens; and a third, the laws of the State of Maryland relating to the collection and disposal of abortion material. The second circular cites our reasons for adopting the present system of classification and it may be interesting to insert a table showing the main groups into which we have classified our first 2,000 specimens. (See next page.) These are arranged in series of 100 each, which we designate as *centuries*.

As may be noted from the table, the specimens are first divided into two main divisions—pathological and normal. Under pathological are seven subdivisions. The first includes all specimens in which only villi are found, the main body of the ovum having disintegrated; in the second group the embryo and amnion are both missing, the chorionic sac having within it only the cœlom filled with magma; in the third the amnion is present but the embryo is not; in the fourth the embryo has been reduced to a small nodule; in the fifth the embryo is cylindrical in form but very decidedly atrophic; in the sixth the embryo is quite well formed but markedly stunted; the seventh group is composed mostly of larger specimens, including fetus compressus and macerated embryos. The second division includes embryos normal in form, and these are arranged in months, according to measurements published in the Manual of Human Embryology, edited by Keibel

Table giving the classification of 2,000 specimens.

Centuries.	Cat. No.	Pathological, in groups. 1	2	3	4	5	6	7	Total.
1	1 to 98	1	5	1	6	4	3	4	24
2	99 205	0	9	1	8	6	13	6	43
3	206 295	2	5	0	3	9	11	7	37
4	296 380	1	7	1	4	9	16	7	45
5	381 476	4	2	3	4	7	9	3	32
6	477 571	4	10	7	7	9	8	6	51
7	572 652c	3	5	4	3	5	5	8	33
8	652d 729	4	7	3	7	12	7	4	44
9	730 816b	8	13	1	5	7	4	11	49
10	817 900g	9	8	0	4	7	4	6	38
11	900h 964	8	6	2	4	6	2	6	34
12	965 1028	6	9	1	4	6	1	12	39
13	1029 1126b	6	6	6	5	10	4	11	48
14	1127a 1202	7	5	4	0	5	7	13	41
15	1203 1292	7	5	1	4	9	10	17	53
16	1293 1365	9	3	2	2	7	8	22	53
17	1366 1458	9	4	2	4	2	3	19	43
18	1459 1545	9	4	2	1	5	8	28	57
19	1546 1641	10	10	6	2	6	8	14	56
20	1642a 1728	8	3	1	7	4	6	11	40
	Total	115	126	48	84	135	137	215	860
	Percentage	5.8	6.3	2.4	4.2	6.7	6.8	10.8	43.0

Centuries.	Cat. No.	Normal, in months. 1	2	3	4	5	6	7	8	9	10	Total.
1	1 to 98	3	41	17	8	7	0	0	0	0	0	76
2	99 205	0	25	21	7	2	2	0	0	0	0	57
3	206 295	1	24	28	7	1	1	0	0	0	1	63
4	296 380	1	21	12	14	2	2	2	0	0	1	55
5	381 476	3	41	11	11	2	0	0	0	0	0	68
6	477 571	0	21	16	4	5	1	0	2	0	0	49
7	572 652c	0	28	21	10	3	2	3	0	0	0	67
8	652d 729	1	18	18	10	4	3	1	0	0	1	56
9	730 816b	1	12	15	15	7	1	0	0	0	0	51
10	817 900g	1	14	21	7	8	6	2	0	0	3	62
11	900h 964	0	13	22	16	12	3	0	0	0	0	66
12	965 1028	0	7	8	16	22	5	2	0	0	1	61
13	1029 1126b	1	10	10	8	7	10	2	3	0	1	52
14	1127a 1202	1	8	17	12	11	6	2	0	0	2	59
15	1203 1292	0	9	14	11	6	2	1	1	0	3	47
16	1293 1365	0	7	13	17	7	3	0	0	0	0	47
17	1366 1458	1	4	5	20	14	4	3	1	2	3	57
18	1459 1545	0	5	10	13	9	4	1	1	0	0	43
19	1546 1641	0	4	15	8	6	2	4	1	1	3	44
20	1642a 1728	0	2	15	12	6	5	9	6	1	4	60
	Total	14	314	309	226	141	62	32	15	4	23	1140
	Percentage	0.7	15.7	15.4	11.3	7.0	3.1	1.6	.7	0.2	1.1	57.0

and Mall, as follows: First month, embryo length from 0 to 2.5 mm.; second month, 2.6 to 25 mm.; third month, 26 to 68 mm.; fourth month, 69 to 121 mm.; fifth month, 122 to 167 mm.; sixth month, 168 to 210 mm.; seventh month, 211 to 245 mm.; eighth month, 246 to 284 mm.; ninth month, 285 to 316 mm.; tenth month, 317 to 336 mm. or larger.

In addition to various papers which have appeared from time to time during the past year, and which are listed in this volume (see Bibliography, pages 36–46), the following have been published by the Carnegie Institution or are in course of publication:

Publication No. 224:
- No. 10. Mall, Franklin P. The human magma réticulé in normal and in pathological development.
- No. 11. Cowdry, E. V. The structure of chromophile cells of the nervous system.
- No. 12. Cunningham, R. S. On the development of the lymphatics of the lungs in the embryo pig.
- No. 13. Macklin, Charles C. Binucleate cells in tissue cultures.

Publication No. 225:
- No. 14. Weed, Lewis H. Development of the cerebro-spinal spaces.

Publication No. 226:
- No. 15. Mall, Franklin P. Cyclopia in the human embryo.
- No. 16. Thurlow, Madge D. Quantitative studies on mitochondria in nerve cells.
- No. 17. Lewis, Margaret Reed. The development of connective-tissue fibers in tissue cultures of chick embryos.
- No. 18. Sabin, Florence R. Origin and development of the primitive vessels of the chick and of the pig.
- No. 19. Johnson, Franklin Paradise. A human embryo of twenty-four pairs of somites.

Publication No. 227 (in press):
- No. 20. Streeter, George L. The histogenesis and growth of the otic capsule and its contained periotic-tissue spaces in the human embryo.
- No. 21. Wheeler, Theodora. Study of a human spina bifida monster with encephaloceles and other abnormalities.
- No. 22. Van der Stricht, O. The genesis and structure of the membrana tectoria and the crista spiralis of the cochlea.
- No. 23. Ingalls, N. W. A human embryo before the appearance of the myotome.

As a sixth contribution on the pathology of human embryos I have published a study on Cyclopia, as one of the papers in Publication No. 226 of the Carnegie Institution of Washington. In this connection it may be of interest to mention that the progress made during recent years in the study of teratology has been so marked that it is now possible to reconsider the whole subject and to place it upon a permanent scientific basis. For this progress we are indebted almost entirely to the experimental embryologists. Problems which formerly seemed impossible of solution—for instance, the formation of double monsters—have yielded as if by magic to the embryologist who made experimental studies upon the living egg. Perhaps the best example that can be brought forward to illustrate this point is the question of the cause of cyclopia. As soon as it was possible to experiment upon eggs in such a way that practically all of them developed into cyclopean monsters, the explanation of this condition was at hand. No important organ develops from the midline of the medullary plate, and this,

in a human embryo 6.5 mm. long, is represented by a thin layer of cells. The motor nuclei arise from the thickenings of either side of the floor plate in lateral ridges known as the basal plates. The narrow, thin floor plate really forms the ventral midseptum of the spinal cord of the brain, and subsequently commissural fibers grow through it to form the raphé. If we view the basal plate from above we find that this raphé extends forward to the neuropore, at which point the raphé fibers are the anterior commissure within the torus transversus. Back of this we have the torus opticus, and its commissural fibers are the fibers of the optic nerve. At an early period in its development the torus opticus evidently widens rapidly and pushes through the rest of the brain, as the optic stalks appear quite suddenly. An injury to the medullary plate at this time would probably make itself felt more upon the optic stalk than upon the eye, since the short period during which it grows rapidly is its critical one. If we cut out the optic stalk or the torus opticus, as Stockard and Lewis did in their experiments, then the foveola would remain together and form cyclopia. It may be added that the anatomical changes found in our small cyclopean human embryos, as well as in all cyclopean monsters, can be explained by the removal of the structures represented along the line of the raphé of the medullary plate, reaching from the mamillary bodies to the neuropore. This includes the torus transversus, which naturally involves the olfactory region and the anterior commissure. Thus we can explain, by a study of these specimens, the anatomical changes in the human brain which are found in cases of cyclopia.

A special study of the laws of bone architecture has been made by Dr. John C. Koch. In this a foundation is laid for the study and mechanical analysis of the spongy bone entering into the structure of other parts of the skeleton, by the application of the principle that spongy bone and compact bone are homogeneous material, and differ chiefly in strength approximately in proportion to other densities. The thickness and closeness of spacing of trabeculæ in bone vary directly with the intensity of the stresses transmitted by them. The general conclusion of the study is that the law of bone holds true mathematically and mechanically in the normal human femur, and therefore for all other normal human bones.

I may mention also the paper of Dr. Schultz on bilateral ossification centers above the squamous portion of the occipital bone, and that of Doctors Goodpasture and Wislocki on old age in relation to cell overgrowth in cancer.

A developmental study of some of the primitive muscular reactions in fetal and new-born kittens has been made by Professor L. H. Weed. By experimental procedures he has determined the effect of decerebration at different stages of development, particularly as regards rhythmic movements of progression. The purpose of these studies has been to

combine physiological observations in developing animals with subsequent morphological examination of the same material, and in this way to make definite progress towards the solution of some of the fundamental problems of the central nervous system. Two papers have been published concerning the reactions following decerebration. It was found that decerebrate kittens do not exhibit an invariable extensor rigidity such as is found in decerebrated adult animals. They give, however, typical scratch reflexes, respond to both dorsal and ventral excitation, and react to trauma to the tail. In general, the animals after decerebration are much more active than are the customary adult preparations. A point of particular interest is that practically all of them show rhythmic progressive movements, and it is possible to separate them into two groups on the basis of this reaction, the groups being determined by the length of time the beats continue. The reactions of the group which show prolonged progressive beats are those of an adult cat, from which only the cerebral hemispheres have been removed. The animals of the second group, however, are somewhat more active than are adult decerebrate cats. In the kittens of the first group an extensor rigidity was usually absent. Where it was not absent a questionable rigidity occurred soon after the ablation, and was quickly abolished by the onset of rhythmic beats of all four legs. As the tendency to progression decreased extensor rigidity became more pronounced, affecting in some only the forelegs. A reciprocal relationship between the prolonged progressive movements and the extensor rigidities seems to be indicated by these experiments.

Dr. Weed has also published a paper regarding the anatomical aspects and the more general processes of the circulation and distribution of the cerebro-spinal fluid, in which is reviewed the history of our knowledge of the pathways of this fluid. He incorporates the results of his own investigations, an account of which was given in my last report.

H. G. Fisher and H. R. Muller have reported their observations upon cats experimentally subjected to unilateral destruction of the semicircular canals. Their particular purpose was to determine the permanency of the functional disturbances produced by such a lesion and the amount of compensation which occurs on the part of other organs. They find that such animals tend to slowly recover from the initial disturbances in their postural and muscular reactions, but that the recovery does not become complete, the longest observations having extended over a period of three months. The characteristic rotation when walking, when dropping through the air, or when submerged in water, occurs always in the same direction—around the long axis of the body and away from the lesion.

During the year an investigation has been completed by Professor George L. Streeter on the histogenesis of the mesodermal tissues sur-

rounding the membranous labyrinth, particular attention being given to the cartilaginous capsule of the ear. This is a favorable place for studying the histological features of the growth of cartilage, for two special reasons: In the first place there are, on account of the intricacy of form of the labyrinth, many kinds of cartilaginous changes found there which are necessary in order to accommodate the growth of the membranous labyrinth; and in the second place the topography is so well marked by known landmarks that all of these changes, as well as the location and direction of growth, can be easily followed. A preliminary report of this study has been published, and therein it is shown that the tissues of the capsule are capable not only of differentiation, but also de-differentiation, throughout a considerable portion of their development. The cartilaginous tissue of the capsule is capable of both progressive and retrogressive changes, and it is this adaptability that makes possible those changes which are necessary in the growth and alteration in form of the labyrinth.

The work of Dr. Streeter on the reticular tissue surrounding the membranous labyrinth and the histological changes involved in the formation of the scala tympani and scala vestibuli, a preliminary account of which was given in my last report, has now been published in completed form. These spaces have been known since the time of Breschet (1833) as perilymphatic spaces, but inasmuch as they have no apparent relation, either in their manner of development or in their ultimate connection with the lymphatic vascular system, the new term *periotic spaces* is used by Dr. Streeter for their designation throughout his description of their development. It is found that these spaces have a very definite morphological individuality. They make their appearance at a definite stage in the development of the embryo, they are formed at definite places, they pass through a series of definite histogenetic processes, and they spread in the course of their growth in a definite order and manner; all of which points to the existence of a definite function on their part.

A critical review of the work which has been done on the lymphatic system during the past fifteen years has been given by Professor F. R. Sabin, in which special attention is devoted to the general subject of tissue spaces and tissue fluids. Professor Sabin calls attention to the fact that these last-named structures are not to be confused with the endothelial system of lymphatic vessels and urges the restriction of the term *lymph* and *lymphatic* to the latter—the true lymphatic system. She has extended her studies on the vascular system to the living chick blastoderm, and by comparing the conditions found there with injected specimens of very young chick and pig embryos has been able to make important observations regarding the origin and development of the early blood-vessels.

The results of this study have been published in the Contributions to Embryology in Publication No. 226, Carnegie Institution of Wash-

ington, 1917. Dr. Sabin was able to observe in hanging-drop preparations of the living chick blastoderm the differentiation of angioblasts from the mesoderm. She found that they form a plexus of solid bands which could be distinguished from the surrounding mesoderm, owing to the fact that they pass through rhythmic cycles of cell division. During a part of this cycle they become very granular and opaque and at that time stand out sharply from the intervening spaces occupied by resting mesoderm. She was able, from such living preparations, to confirm by observations the experimental evidence of Hahn, Miller and McWhorter, and Reagan, that angioblasts are differentiated not only in the membranes, as originally described by His, but also within the body of the embryo. The aorta is shown to arise, in part at least, from angioblasts differentiating *in situ* from mesoderm, but there is some evidence that this is also true of the primitive plexus of vessels on the surface of the nervous system.

Dr. Sabin's paper includes a detailed description of the primitive blood-vessels of the chick and pig in which injections have been made at earlier stages than have heretofore been published. The development of the first true head-vein—the vena capitis prima—is described as arising in three segments. The anterior segment, draining the forebrain and midbrain, originally empties into the primitive vessels or capillary sheet of the hindbrain; the posterior segment, which eventually unites the other two, is derived from the capillary loops which connect the visceral arches with the anterior cardinal vein. With the establishment of this continuous lateral channel the primitive vessel of the hindbrain is released from the function of draining the forebrain and spreads as a pial plexus over the wall of the hindbrain, in which are subsequently developed longitudinal arterial vessels. This establishes the interesting fact that vessels which at one stage of their development would be called venous, at a later stage may become arterial, and in them the direction of the flow of blood is entirely changed.

The subintestinal artery in the pig and chick is cited by Dr. Sabin as another example of an entire change in function on the part of a vascular plexus during the course of its development. The constant alteration in the form and communications of the primitive vascular system makes it necessary to redefine the term *artery* and *vein*, as applied in the embryo. Instead of naming blood channels according to the vessels for which they form the primordia, Dr. Sabin recommends naming them for the different stages, according to the functions they perform at that particular time.

A morphological study of the early development of the ureter and the embryological aspects of the occurrence of double ureter has been made by Dr. E. G. Davis. In collaboration with Dr. Hugh H. Young, this work, together with a clinical study of the condition as occurring in adults, has been published.

The work done on cytology in this department may be grouped under two headings—descriptive and experimental. The descriptive work comprises papers by Professor Jules Duesberg and by Mr. Norman Clive Nicholson. It should be added that Miss Thurlow's paper, reported last year after the manuscript was read at the meeting of the Anatomists, has since appeared in full, with figures, in the Contributions to Embryology of the Carnegie Institution (No. 226).

Professor Duesberg, applying the methods for chondriosomes to fish embryos, found these bodies in all the cells of such embryos from the segmenting stage up to the time of hatching. In the first blastomeres the chondriosomes are granular (mitochondria) and are especially numerous in the marginal cells. Later, filaments (chondrioconts) are found almost exclusively. Dr. Duesberg's paper contains a detailed description of the chondriosomes in the cells of the epiderm, central nervous system, ganglia, chorda, mesenchyme, Wolffian ducts, and digestive tract; also in blood corpuscles, myoblasts, and primordial germ-cells. It was found that in mitosis the shape of the chondriosomes was somewhat modified, inasmuch as frequently the filaments break into smaller pieces, and that they become accumulated in the anaphase between the daughter-nuclei, as observed in cells of embryos of other vertebrates. These observations show that the structure of the cell in fish embryos is essentially the same as in other groups. The protoplasm is formed of a ground substance, appearing homogeneous in the preparations, and of variously shaped chondriosomes.

Mr. Nicholson has studied the qualitative variations in the mitochondria of nerve-cells in white mice. He finds that the variation in morphology between cells of different varieties is often quite pronounced. Filamentous mitochondria constitute the most common form met with in the cells of the central nervous system. They are particularly apparent in the large anterior horn-cells and in the large cells of the reticular formation. Rod-like and granular mitochondria are more rare, but are characteristic of the cells of the mesencephalic nucleus of the fifth nerve as well as of the cells of the Gasserian ganglion. The cells of the nucleus of the corpus trapezoideum may be distinguished by their large, swollen, block-like mitochondria. There is also, in the majority of cases, a variation in the form of mitochondria in different parts of the same cell. For instance, they are usually more granular in the vicinity of the nucleus than in the peripheral parts of the cytoplasm or in the processes. In the latter they are invariably rod-like or filamentous. The cells of the nucleus of the trapezoid body constitute a special case, because in them the mitochondria always occur in the form of long blocks in the peripheral cytoplasm, in sharp contrast to the minute, granular, and rod-like mitochondria in the immediate neighborhood of the nucleus. The mitochondria not only occur between the Nissl bodies (as is generally believed), but are embedded in them.

The experimental side of cytological investigation is represented in this year's work by two papers on mitochondria (B. Strongman and W. J. M. Scott), a paper on the development of connective-tissue fibers in tissue cultures (Margaret R. Lewis), and a number of others on the subject of vital dyes (Macklin, Shipley and Macklin, Wislocki, Shipley, and Cunningham).

Miss Strongman endeavored to ascertain if changes occur in the mitochondria of nerve-cells after prolonged nervous activity. She used white mice and made them swim until they were exhausted. No definite changes could be detected, either in the number or the form of these bodies.

Mr. Scott studied the effects of phosphorous poisoning on mitochondria in the pancreas of white mice. It appears that mitochondria are the first constituents of the acinus cell of the pancreas to show pathological changes in phosphorous poisoning. They lose their filamentous form, become shorter and thicker, and the bleb-like swellings so characteristic of the normal pancreas completely disappear. Then follows the stage of agglutination, in which the mitochondria collect in large clumps and fuse to form droplets possessing the characteristic properties of lipoids.

Mrs. Lewis summarizes her studies on the development of connective-tissue fibers as follows: The connective-tissue fibrils begin to develop in the subcutaneous tissue of chick embryos of from 9 to 10 days' incubation, and appear as well-developed fibers in the subcutaneous tissue of a 12-day chick embryo. The cut fibers which are present in the explanted piece of subcutaneous tissue from an 11 to 15 day chick embryo do not grow either in length or bulk in the tissue cultures. The fibrils develop as delicate lines of the exoplasm of the cell, and the bundles later pass over or through the exoplasm of several cells as a definite fiber. There is evidence that the fibrils are formed by a secretory activity of the *grains de ségrégation* (vacuoles) of the connective tissue. The fibrils of the epithelial cells of the amnion appear to form in the same manner as those of the subcutaneous tissue—*i. e.*, from the exoplasm of the cell, and not from the fusion of the walls of the vacuoles.

Dr. C. C. Macklin used madder to feed animals which possessed calcium-salt concrements of different kinds, the idea being to find out whether the processes underlying the formation of normal bone and of pathological calcific deposits are, as claimed, really similar if not identical. In experimental calcification of the kidney, obtained through unilateral ligation of the renal vessels, and under the intermittent influence of madder feeding, the calcific deposits were found stained. From these results it is believed that all pathological calcific deposits in process of formation will stain with madder.

Doctors Shipley and Macklin studied the bones of young animals after injections of trypan blue into the peritoneal cavity. They found

that pyrrhol cells occur in regions where bone is developing, and are most numerous in areas where the resorption of bone and cartilage is most active. It may therefore be considered that they take some part in this process, and it is believed that they ingest the débris and assist in clearing it away. The osteoblast is not trypanophilic and hence must be excluded from the class of pyrrhol cells and their derivatives, such as the foreign-body giant cell. The same authors used the vital-staining method, combined with Spalteholz's clearing method, for the demonstration of centers of osteoblastic activity. The epiphyseal and apophyseal centers, colored in deep blue, are soon embedded in their transparent cartilaginous matrices. The growing ends of the diaphysis are much more darkly stained than the remainder of the bone shaft. The unique feature of this method is that it demonstrates clearly the different ossification areas, even before the process of deposition of calcium salts has occurred to any marked degree. In centers where, by former methods, the new bone is almost, if not quite, invisible, owing to the small amount of calcium present, this method brings out the seat of ossification quite distinctly.

Dr. G. B. Wislocki describes a new technique, in combination with Clark's method and sections, for studying the growth of lymphatics. It consists in vitally staining amphibian larvæ and observing the lymphatics, whose endothelium stains quite specifically *intra vitam* with acid-azo dyes. With this method the growing lymphatics were readily studied, as the lymphatic endothelium was distinguishable at all times from mesenchyme cells or vascular endothelium, owing to its characteristic stain. Wislocki also studied the behavior of trypan blue injected into the peritoneal cavity of teleosts. After a few hours there appears a gradually developing blue coloration of the integument. The benzidine dyes are phagocytized by the endothelium of the hepatic sinuses, analogous to the Kupffer cells in mammals, and by the reticulo-endothelium of the spleen, as also by the endothelium of the renal portal system. There is furthermore a widespread storage of vital dye on the part of the endothelium of the lymphatic vessels, a condition also noted in amphibian larvæ, but never known to occur in mammals.

DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. DAVENPORT, DIRECTOR.

Among the principal advances of the year have been:

(1) The demonstration of the parallelism of the mutations in related species of the fruit-fly, *Drosophila,* and further evidence for the conclusion that the factors for them occupy corresponding places in the chromosomes.

(2) The discovery of a set of conditions of the environment which induces the appearance of males in a parthenogenetic species of entomostraca.

(3) The demonstration of the great effect of inhalation of alcohol on the growth and fecundity of rats.

(4) The acquisition of additional evidence that the *gradual* change in the somas of a population by selection of parents may be due merely to the isolation of individual factors out of many concerned with the same trait.

(5) The analysis of a new method of selecting the best egg-laying birds in a flock of poultry.

(6) The discovery of a form which acts much like a dominant mutant in jimson weed but which seems to depend on a parasite for its production.

(7) The production of a "pure" highly abnormal race of beans.

(8) The analysis of the juvenile traits and hereditary characteristics of successful naval men.

(9) The discovery of a method of forcing pigmentation in albinos.

(10) The discovery of an extraordinary variability in sap concentration in plants, which throws light on the rise of sap in trees, on the acquisition of food from their hosts by parasitic phanerogams, and on the relation of sap properties to the solutions in the substratum.

(11) The origination of mutations that are sterile with the parent species.

(12) The completion for press of the unpublished scientific work of Professor Charles O. Whitman.

STAFF.

The work of this Department during the present year has been carried on by seven resident investigators and various associates and assistants. In addition to his administrative duties the Director has prepared for publication a work on naval officers, their juvenile traits and family history. As a member of the Anthropological Committee

*Situated at Cold Spring Harbor, Long Island, New York.

of the National Research Council he cooperated in the report of the committee concerning physical criteria for the selection of recruits. Dr. J. A. Harris, besides carrying on here his extensive series of breeding experiments on beans, went to Florida and to the Dismal Swamp, North Carolina, to study the relations of tissue sap to the environment of plants. Dr. A. M. Banta, assisted by Mr. Obreshkove, has continued his extensive breeding experiments on sex in daphnids and has been getting into final form for publication his work on selection of strains of daphnids for sensitiveness to light. Dr. O. Riddle completed his editorial work on the Whitman manuscripts and is preparing a book embodying his researches on sex in pigeons. Dr. E. C. MacDowell, assisted by Miss Vicari, has continued his work on the effect of alcohol on the germinal qualities of rats. Dr. C. W. Metz continued his study on the evolution of the germ-plasm of Drosophilidæ. Dr. A. F. Blakeslee continued his genetic studies on plants and directed the work on poisons of the bread-mold carried on at this Station at the expense of the U. S. Department of Agriculture. He is also improving the adzuki bean as "an emergency war-research problem." During July to September Dr. Aute Richards, of Wabash College, was a guest at the Station, studying, cytologically, Dr. Banta's sex-intergrading daphnids; also, Dr. John Y. Pennypacker, of the University of Pennsylvania, studied, histologically, abnormal seedling beans.

REPORTS ON INVESTIGATIONS.

THE GERM-PLASM AND ITS MODIFICATION.

COMPARATIVE STUDY OF THE CHROMOSOME GROUPS IN DIPTERA.

Dr. Metz has during the year devoted some time to extending his studies on the chromosomes in the Diptera, and especially on their behavior in spermatogenesis. He has almost completed a study on spermatogenesis in the Asilidæ and one on spermatogenesis in the Drosophilidæ. Since the chromosomes are doubtless to be regarded as the true specific stuff, a study of their forms, and especially of the evolution of the chromosomal complex, becomes of great interest. Dr. Metz has shown that, starting with the generalized form found in *Drosophila ampelophila,* 12 types of chromosome-complexes may be distinguished in related species which are merely modifications of that generalized form. These types are shown in figure 1. It will be seen that A consists of 3 pairs of large chromosomes and 1 pair of small ones. Of the 3 large pairs one (the lower in each drawing) is the sex-chromosome pair. Of the others one or both may be divided, resulting in 4 or 5 large pairs. Thus in F there are 5 pairs of large chromosomes and 1 pair of small ones. The foregoing series doubtless represents stages in the evolution of the chromosome-complex—the germ-plasm—of one group of genetically related organisms.

COMPARATIVE STUDIES ON THE GERM-PLASM OF DROSOPHILA.

Dr. Metz initiated two or three years ago a series of breeding experiments on other species of *Drosophila* to provide for a detailed genetic comparison with the results on *Drosophila ampelophila*. Such a comparison involves numerous questions of wide genetic and evolutionary significance, as well as several of more technical interest. On some of these questions definite evidence has already been obtained, chiefly by the breeding of *Drosophila virilis*, although the work has not yet reached its most important stages. Among the results attained by Dr. Metz largely or wholly within the last year, he considers the following as the most important:

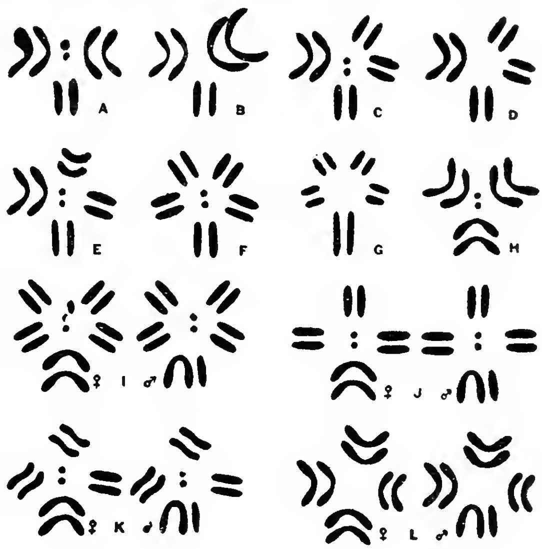

Fig. 1.

With regard to the relative mutability of species.—On this point the evidence from *virilis* indicates a degree of mutability at least equal to that in *ampelophila*. Hence the supposed phenomenal mutability of the latter is not limited to one species alone. At least 23 mutant races have been obtained in *D. virilis* up to date. Considering the relatively limited number of individuals examined, this undoubtedly represents a rate of mutation approximately equal to that of *ampelophila*.

With respect to the nature of mutations arising in related species.—On this point the evidence agrees with expectation in that the mutants in *virilis* are of the same general types as in *ampelophila; i. e.*, they represent modifications in the color, shape, and structure of the eyes, in the color and shape of the body, in the size, shape, and venation of the wings, in the number and morphological character of the bristles, etc. Some of these modifications show strong indications of actually being homologous in the two species—a point that will be considered later.

With respect to the phenomena of linkage and "crossing-over" in related species.—Most of Dr. Metz's work has centered around this feature. In general the results show a series of linkage and cross-over phenomena similar to those in *ampelophila*, leaving no doubt that the genetic processes are fundamentally the same in the two species. One especially significant point of resemblance is in the dissimilar genetic behavior of the two sexes. In *ampelophila*, as is well known, crossing-over occurs only in the female; linkage is absolute in the male. This is a genetic

peculiarity not found in all organisms and probably results from peculiarities in chromosome behavior. In *virilis* Dr. Metz has found this sexual difference to exist exactly as in *ampelophila.* At least this is true in respect to all of the characters thus far studied and they are sufficient to give strong evidence of the universality of the rule in this species.

With respect to the general chromosome theory of heredity.—*Drosophila virilis* provides an exceptionally good opportunity to test this theory by means of a comparison between its linkage phenomena and those of *ampelophila.* In *ampelophila* there are 4 pairs of chromosomes and 4 groups of linked factors to correspond; in *virilis* there are 6 pairs of chromosomes and hence, according to the hypothesis, there should correspondingly be 6 linkage groups. It is very significant, Dr. Metz believes, that 5 such linkage groups have already been located in this species. Since this is one more than the number in *ampelophila,* it argues strongly in favor of the chromosome hypothesis and makes it probable that the discovery of the sixth group is only a matter of time.

With respect to the relations between corresponding linkage groups in related species.—Data on this subject are furnished by the sex-linked factors in *virilis* taken in connection with those in *ampelophila.* Eight factors belonging to the sex-linked group in *virilis* have been carefully studied by means of crosses involving various combinations of characters. This series of experiments alone has involved upwards of 10,000 individuals. As a result the sex-linked factors are found to be related, upon the basis of linkage, as shown in the accompanying diagram. It is significant that they fall into a linear series just as do those of *ampelophila,* and that when the position of a factor is known with respect to any two previously located factors, one can predict its position with respect to any other factor in the series.

FIG. 2.—Chart of the sex-chromosome in *Drosophila virilis.*

y, yellow; *fr,* frayed; *v,* vesiculated; *h,* hairy; *m,* magenta; *f,* forked; *r,* rugose; *g,* glazed.

Comparing this linkage group as a whole with that of *ampelophila,* its relatively greater "length" is to be noticed at once. Similarly constructed diagrams in the two species are respectively 67 to 68 "units" (*ampelophila*) and 80 to 90 "units" (*virilis*)—a unit representing 1 per cent of crossing-over. Since the "length" increases somewhat with an increase in the number of factors involved in a given region (*i. e.,* the length is thus more accurately determined, because double crossing-over is largely eliminated), the discrepancy is really greater than that indicated in these figures and the diagram in *virilis* will probably include 90 to 100 units when more intermediate factors are studied. This leaves no doubt that there is a difference in "length" of the two linkage groups here; and since "length" represents amount

of crossing-over, it appears that crossing-over is more frequent in *virilis* than in *ampelophila*. Whether this is due to a difference in the length (or amount) of the sex-chromosome involved in the two cases (assuming that the chromosomes carry the factors) or to an actual difference in rate of crossing-over per unit of chromosome length, is not certain, but the available evidence suggests the latter.

With respect to the relation between particular characters and their factors in two related species.—Striking, although not extensive, evidence has been obtained on this question. It was partly included in last year's report, but has been more fully worked out this year. Two of the mutant characters in *virilis*—"yellow" body-color, and "forked" bristles—appear to be almost exact duplicates of two in *ampelophila*. A careful comparison under the microscope reveals a remarkable likeness in each case, and there seems to be great probability that the characters are actually homologous in the two species. Considering this fact, it is very significant to note that in both cases the characters are sex-linked and that their factors occupy similar relative positions in the factorial (linkage) group. Such a series of correlations strongly suggests a common germinal basis in the two species—in other words, lends material weight to the assumption of a definite organization in the germ-plasm and to the assumption that this organization persists from species to species.

In addition to the above more or less anticipated results, another series of phenomena of an entirely different nature was observed. This bears more particularly upon the general question of "evolution by mutation." The case is as follows: Two sex-linked mutants (allelomorphs) were found in hybridization experiments to exhibit an incompatibility that differs little, if any, from cases of incompatibility between species in nature. When reciprocal matings are made between these mutants one of the combinations entirely fails to produce offspring and the other gives hybrids that are all sterile. As a result, it is impossible to get a second generation from the cross. To Dr. Metz's mind this suggests the possible origin of species in nature by means of mutations that involve incompatibility. If three forms exist in nature (as they do in the laboratory), of which two are fertile with the third but infertile with one another, then the disappearance of the third form, by means of natural selection or otherwise, would leave the other two isolated as distinct species. No matter how slightly they differed to begin with, the fact of isolation would allow them to develop independently and to diverge into well-marked species.

EFFECT OF ALCOHOL ON GERM-PLASM.

The study of the effects of alcohol upon the germ-plasm of rats, described in earlier reports, has been continued during the year by Dr. MacDowell. While he has accumulated many data, it has been thought best, before publishing, to note the results on a new set of

experiments. In this new set the amount of alcohol given has been greatly increased and certain changes have been made in the method of training; also, a new stock of rats from the Wistar Institute was made use of. The treated rats were left in the alcohol-vapor every day until they were in deep stupor.

While it is not possible, as yet, to give the results of this new experiment in relation to the main problem, certain side-topics have received much light. The effect of the alcohol upon the growth of the rats receiving it has been determined. Weekly weighings have been made of all the alcoholized rats and their normal controls and from these weights individual growth-curves have been plotted. The average size at stated ages has been found. These results are given in table 1. Since the females were continuously breeding, only males are included in the data given. The loss in weight of the alcoholics after 6 months of alcoholization amounts to more than 20 per cent of the weight of the normals.

TABLE 1.—*Average weights, in grams, of alcoholized male rats compared with their normal brothers.*

Age in days.	Normals.		Alcoholics.		Differences; normals heavier by—
	Average weight.	No. of rats.	Average weight.	No. of rats.	
30	45.4	22	46.2	27	0.8
40	74.5	22	70.5	27	4.0
60	128.7	22	116.1	27	12.6
90	174.9	22	142.3	27	32.6
120	239.8	21	192.5	22	47.3
151	267.0	18	211.7	16	55.3
182	285.0	13	227.1	10	57.9

TABLE 2.—*Fecundity records of alcoholic rats compared with normal rats.*

[Matings of the alcoholics and the corresponding normals made on the same day, and the record of births taken during equal periods.]

Group.	No. of pairs.		No. of young born.	
	Alcoholics.	Normals.	Alcoholics.	Normals.
A	10	10	23	75
B	4	3	13	31
C	7	8	30	81
KC	9	8	42	113
Total.	30	29	108	300

Another immediate effect of alcohol is upon the fecundity. In one set of experiments a male and a female rat that had been alcoholized were mated and the number of their progeny was compared with that of unalcoholized controls. The results are given in table 2. Since 30 pairs of alcoholized rats produced 108 young, while 29 pairs of unalcoholized rats produced 300 young, it can not be doubted that the imbibition of alcohol causes, either directly or indirectly, a reduction in the number of offspring born.

A test was made also upon the learning capacity of the alcoholized rats as compared with that of their normal brothers and sisters. The training was given each morning before the alcohol was administered. No summaries have been made from these data.

A study of the second generation, which constitutes the main objective of the experiment, has been pushed rapidly ahead. A large number of rats (see table 3) has been taken through a 3 months' schedule, but no summary of the results can be offered at present.

TABLE 3.—*Number of rats trained November 1916 to August 1917.*

	Total.
Parents	12
First generation offspring (alcoholized, 62; normal, 57)	119
Second generation offspring (from alcoholized parents, 49; from control parents, 66)	115
Second generation offspring (one parent alcoholized and one normal, 6; from control parents, 7)	13
Total	259

EFFECT OF STARVATION ON THE GERM-PLASM OF BEANS.

Dr. Harris has continued his studies on the influence (or rather the absence of influence) of the depauperization through starvation of the earlier generations upon later generations of beans. This work is nearly completed.

ALTERATION OF THE QUALITY OF THE GERM-PLASM OF A POPULATION BY SOMATIC SELECTION.

Experiments with Drosophila.—The question of the degree to which the quality of the germ-plasm of a population may be altered by somatic selection remains much mooted, despite Castle's prolonged investigations of the subject. During the year under review Dr. MacDowell has contributed to this topic in his paper, "Bristle Inheritance in *Drosophila:* II. Selection." Like Castle in his studies of rats, MacDowell with *Drosophila* has selected for more and for less, only MacDowell, unlike Castle, has dealt with a numerical trait—the number of bristles on the back of this rapidly breeding fly. Castle has selected his rats for only 16 or 17 generations; MacDowell selected his flies for 49 generations. Castle believes his experiments prove that by selecting parents with the greatest amount of pigmentation the germ-plasm in the later generation tends to produce a more extensive pigmentation than in the earlier generations and that this change may go on indefinitely or until the rat is entirely covered with pigment.

MacDowell, from his more extensive numerical series, concludes that, at the beginning, selection as parents of individuals with the greatest number of bristles isolates a many-bristle-producing germ-plasm. But the maximum potentiality in this respect is reached in about 8 generations, after which the somatic selection does not result in the isolation of a germ-plasm with the potency of still more bristles. The effect of somatic selection on the quality of the germ-plasm of the population is thus *nil* after the germ-plasm has been rendered homozygous in consequence of the selection of the first 8 generations.

Experiments with pigeons.—In our pigeon pens Dr. Riddle has discovered two fully pigmented but "weak" individuals, male and female (in whose immediate ancestry or collaterals no whites have appeared) that have become progenitors of lines in which for four generations partially white pigeons have appeared. Inbreeding and "crowded reproduction" have been practiced. In a second line, pigeons of partially white plumage occurred in one branch of the ancestry. Inbreeding, "crowded reproduction," and selection have been practiced in this series also and in the later generations birds with increased white in the plumage have arisen. In both of these lines, however, the darkest forms have also been selected for breeding, and from these forms also partially white birds have been produced; and greater amounts and proportions of white were obtained, as in the cases cited above, from the later eggs of the the season; *i. e.*, from those obtained under "crowded reproduction."

THE SIGNIFICANCE AND CONTROL OF SEX.

SEX IN PIGEONS.

Dr. Riddle has continued his studies on sex in pigeons. The results of these studies he has recently stated in the following terms:

"The studies that have thus far been made on sex, and on the experimental control of sex, in pigeons go very far, we believe, toward an adequate demonstration that germs prospectively of one sex have been forced to produce an adult of the opposite sex; that germs *normally* female-producing have, under experiment, been made to develop into males; and that germs which were prospectively male-producing have been made to form female adults. That neither selective fertilization, differential maturation, or a selective elimination of ova in the ovary can account for the observed results. Further, and perhaps of more importance, these studies throw much new light on the nature of the difference between the germs of the two sexes. This difference seems to rest on modifiable metabolic levels of the germs; males arise from germs at the higher levels, females from the lower; and such basic differences are quantitative rather than qualitative in kind."

Support for Dr. Riddle's views as to the significance of sex are believed by him to be given by certain recent discoveries. Thus he finds, first, that in pigeons a high proportion of the males that result from crosses between genera bear testes whose size and shape relations are reversed from the condition normal for males and approach the

conditions found in normal females. The significance of this lies in the fact that it is in the wide (generic) crosses that we are able to obtain males from eggs of initial female-producing tendency. In other words, additional evidence is thus obtained for the reality of sex-control in the generic crosses; and in this group of male hybrids the gonads frequently retain or approximate to the gonad size and weight relations of the female.

Dr. Riddle has obtained two pairs of identical twins among the pigeons. Both were pairs of females. He says:

"The importance of the finding lies in the fact that the *storage metabolism* of the germs (ova) which produced these pairs of twins is known to have been higher than in the other ova which arose from the same ovaries and which produced only single (not twin) embryos. It seems that similar information concerning the germ from which such twins have arisen in any other animal forms has never hitherto been obtained. In addition, the fact that the two twin-producing ova were of *high storage value,* and both produced *females,* is a further confirmation of my views as to the metabolic basis of sex."

SEX DETERMINATION IN CLADOCERA.

Dr. Banta has made marked progress in his studies of sexuality in *Daphnia* and related genera. He reports as follows:

"With my work the most important and most desired advance of the year has been in the further light obtained as to the factors controlling sex in *Cladocera.* The general and long-standing belief has been that there is a periodicity in the occurrence of sexual forms in *Cladocera* and that this is controlled by internal factors. In former reports (1915 and 1916) I pointed out that the long-continued and uninterrupted parthenogenetic reproduction in the five species being bred in the laboratory did not result in reduced vigor or in any evidence of need for sexual reproduction. I also pointed out that in the few isolated cases in which males had appeared in the laboratory cultures there was evidence of changed environmental conditions as the causative factors. During the past year overwhelming evidence, it seems to me, has been obtained that environmental factors induce the occurrence of sexual forms."

Evidence from the observed incidence of males.—It may be safely stated that with our methods of handling and observing the *Cladocera* material few males occur without our knowledge; yet for a period of $5\frac{1}{2}$ years 7 strains of *Daphnia pulex* passed through, on the average, more than 225 generations in the laboratory cultures without producing males or sexual eggs. For a lesser period of time, but throughout 186 generations, of 10 strains of *Simocephalus vetulus* no males or fertilizable eggs were produced (except under the special conditions obtaining in the sex-intergrade strain). Of 5 lines of *Moina* 150 generations and of 3 lines of *Simocephalus serrulatus* 65 generations did the same. During 146 generations of *Daphnia longispina* males had occurred only twice and then only in very small numbers. Additional strains (many of which are no longer being bred) of all the above species have been in the laboratory for various lengths of time. None of them produced males.

Table 4 gives an account of the history of all the strains at present in the laboratory, together with the records of their production of males.

TABLE 4.—*Male production in pure strains of Cladocera.*

Species.	Number of strains.	Length of time bred, to May 1917.	Number of generations to May 1917.	Occurrences of males.		
				Previous to May 1917.	Number of strains in which— Males occurred.	Number of strains in which— Males did not occur.
		months.				
Daphnia pulex......	7	66	219–233	None, except in some discarded material of this stock.	4	3
	2	26	96– 97	Do..............	1	1
	3	23	81– 85	Do..............	2	1
Daphnia longispina ..	3	42	133–157	Some at two different times.	2	1
	3	7	20– 25	None..............	3	..
Simocephalus vetulus.	7	57	182–195	In sex-intergrade strain only.	4	3
	3	55	181–186	None..............	3	..
	6	29	91– 97	None..............	5	1
Simocephalus serrulatus.	3	19	63– 67	None..............	3	..
	10	1½	4– 6	None..............	10	..
Moina brachiata	5	22	145–155	None..............	5	..
	52	......	....		42	10

In marked contrast with the extreme rarity of the occurrence of males in the cultures, in May 1917 males suddenly began to appear in the laboratory in numbers and in the vast majority of the strains. There were males in 7 of the 12 strains of *Daphnia pulex;* in 12 of the 16 strains of *Simocephalus vetulus;* in all of the 5 lines of *Moina;* in all of the 13 lines of *Simocephalus serrulatus*, and in all except one of the 6 strains of *Daphnia longispina*. Thus in 42 of the total number of 52 strains in the laboratory, males occurred within a short time and in considerable numbers. Yet this material consisted of 5 different species of 3 genera of *Cladocera*, was obtained from various localities, including two Florida localities separated by nearly 100 miles, and had been reproducing parthenogenetically in the laboratory for periods varying from 1½ months to 5½ years and had descended solely by parthenogenetic reproduction for from 4 to 233 generations. Of *Daphnia pulex*, 7 lines had been in the laboratory for 66 months and had descended 225 generations during that time without producing males; 2 other lines of the same species had been in the laboratory for 26 months and 96 generations, and 3 others for 83 generations, exclusively female; yet 7 out of 12 of these strains produced males at the same time. Likewise with the other species, 3 lines of *Daphnia longispina* reared

for 145 generations, and 3 for 22 generations produced males in all but one line. With *Simocephalus vetulus* 12 of the 16 strains, some of which had been in the laboratory for 188 generations, the others for 81 to 97 generations, produced males; 3 lines of *Simocephalus serrulatus* reared in the laboratory for 65 generations and 10 lines—one from Lakeland, Florida, and 9 from Eustis, Florida—reared for only 4 to 6 generations responded almost simultaneously in the production of males. With *Moina* the story is the same; all the lines produced males at once.

Such synchronism in independently reared and diverse stock can be thought of only in terms of a common influence. It seems a logical impossibility that this synchronism could be due to an internal factor, for it seems hard to believe that in 42 out of 52 strains of quite diverse material the appropriate periods for production of males in an innate sexual cycle should occur almost simultaneously. One must then ascribe the synchronism to an external—an environmental—factor or, perhaps, to a number of such factors.

It was noted in last year's report that in cases in which males had been observed environmental changes had obviously occurred. In the present case the environmental influence was strongly in evidence. In the outdoor pond from which the culture-water was obtained males were occurring in great numbers in the wild stock—just as in the few earlier and very restricted occurrences of males in the laboratory, males had been noted in the wild stock in the outdoor ponds from which the culture-water was gotten, or else (in the absence of wild stock in the outdoor ponds) the culture-water was recognized as somewhat different from the material ordinarily used. During none of the earlier occurrences of males in outdoor ponds had there been such a great number of males either in the ponds or in the laboratory as during the past spring. During the recent epidemic of males the environmental influences tending to produce males were very much more pronounced on the wild stock as well as upon that reared in the laboratory.

Experimental evidence.—Direct experimental evidence adds to the conviction (if additional evidence were necessary) that environmental factors cause the production of males.

In one of these experiments the newly released young of a single brood from one mother were used. These were isolated in individual bottles—5 in culture-water from a pond in which were present great numbers of males of another species of *Cladocera*, and 4 in water from a pond in which no males were present. None of the latter 4 produced any males; all of the 5 in food material from the pond in which occurred wild males produced males.

In another experiment, similarly conducted, food from two sources was used. Different bottles of each food were given different chemical treatment. A small amount of alkali was placed in some and a small amount of acid in others. Still others were untreated. The result was as shown in table 5.

TABLE 5.

Culture-water.	Untreated.	Acid added.	Alkali added.
Pond I.........	3 mothers, all female young.	2 mothers, all male young. 1 mother, dead.	3 mothers, all female young.
Pond II........	2 mothers, all female young. 1 mother, all male young.	3 mothers, all female young.	2 mothers, all male young. 1 mother, all female young.

Where acid was added to the solution from Pond I, "all male" broods were produced; when untreated or with alkali added to this solution "all female" broods were produced. Just the reverse was true with the food solution from Pond II; the addition of alkali producing "all male" broods in 2 out of 3 cases and the addition of acid resulting in "all female" broods. There was 1 "all male" brood in the untreated food from Pond II. These are not completely differential results, but they are suggestive and, considered in connection with other experiments, this significance becomes unmistakable. Other sets of experiments similar to the two mentioned above resulted similarly. The experimental evidence may be said to have considerable weight.

The experiments were not all equally successful, however, and some produced no significant results at all. This lack of uniformity in the experimental results is attributed to variable factors in the culture-water. While the culture material is more or less the same at all times, it will readily be recognized that at different times considerable differences occur in the constituents of an outdoor pond-water in which live many small and larger organisms. So far as the relative degree of alkalinity is concerned, it apparently operates to influence the sex of the daphnids through some other factor or factors; hence it is a controlling influence apparently working through an unknown environmental factor. Its control of sex is none the less significant, however. (A standard culture medium, Dr. Banta suggests, would afford excellent opportunity to attain complete control of sex.)

Production of ephippia.—Strange as it may seem, the production of ephippia does not ordinarily occur in the laboratory simultaneously with the production of males, and frequently males and ephippia do not coexist in outdoor ponds. There is evidence that the production of ephippia, too, is controlled by environmental factors.

Origin of a second sex-intergrade strain.—During the occurrence of males in the spring, sex-intergrades were produced, in Dr. Banta's cultures, by several mothers in one of the strains of *Daphnia longispina.* These were mothers which also produced normal males. Propagation from these sex-intergrades has resulted in the establishment of a strain of sex-intergrades of *D. longispina.* This strain produces, in addition to normal females, sex-intergrades in every generation.

There are 8 easily recognized secondary sex-characters in this species: (1) *Body size*—the males are smaller than the females; (2) *outline of the head*—in the male the head-outline does not form a definite beak as it does in the female; (3) and (4) *character of the first pair of antennæ*—these in the male are considerably developed and distinctly different from the very rudimentary structure in the female; (5) and (6) *outline and hairiness of the ventral anterior margin of the carapace*—in the male this margin forms almost a right angle and is quite covered with hairs, in the female the margin is gently rounded and hairless; (7) and (8) *character of the first pair of thoracic appendages*—in the male these are relatively simple structures armed with a hook-shaped, finger-like projection; in the female they are branched into many long terminal filaments, while there is nothing resembling the hook-like structure of the male. These 8 secondary sex-characters, together with the character of the gonads (which is readily determined by microscopical examination of the living animal), make it possible to state definitely the degree of intersexuality of each individual intergrade (fig. 3).

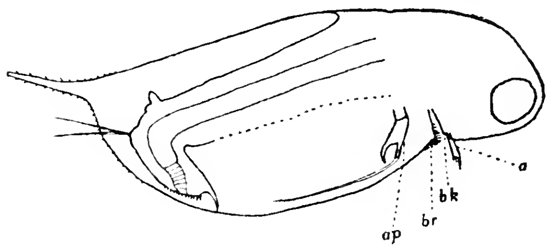

FIG. 3A.

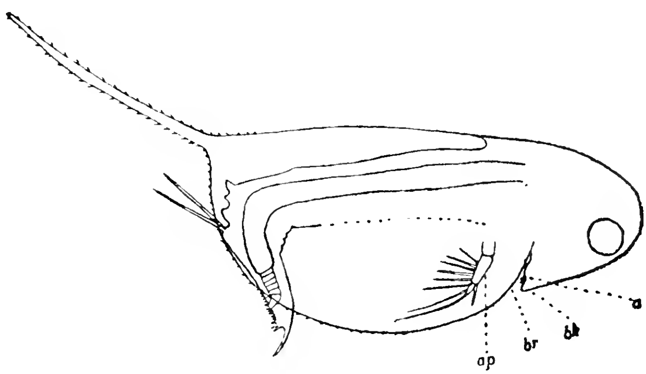

FIG. 3B.

a, antenna; *br*, breast (ventral anterior margin of carapace); *bk*, beak; *ap*, first thoracic appendage.

FIG. 3A. Normal male from sex-intergrade-producing strain of *Daphnia longispina*.

FIG. 3B. Normal female from sex-intergrade-producing strain of *Daphnia longispina*.

Sex intergrades may have any combination of these significant male and female secondary sex characters. Further, these characters are often present in intermediate condition. Obviously with such a sex difference as that between the female and male first thoracic appendage there is room for a wide variety of intermediate conditions. Such a great range actually occurs.

The intergrades are of all grades, ranging from female intergrades with one of the secondary sex-characters slightly male to female intergrades with all of the secondary sex-characters fully and strongly male. In the *Simocephalus* sex-intergrade strain reported a year ago there occur in addition to some normal females and many female intergrades: (1) a few hermaphrodites with various combinations of male and female secondary sex-characters; (2) some male intergrades with one to several female secondary sex-characters; and (3) a great many normal males. In the new *Daphnia longispina* sex-intergrade strain, however, no hermaphrodites or male intergrades have so far been observed while normal males are extremely rare in this strain, whereas in the *Simocephalus* intergrade strain a considerable percentage of the individuals are normal males. The sex-intergrade strain of *Daphnia longispina* runs distinctly less toward maleness than does that of *Simocephalus.*

In other regards the two strains possess many characters in common. Both strains of sex-intergrades vary in their productivity. The more highly male a female intergrade is the less productive she is likely to be. Most of the female intergrades which have most of their secondary sex-characters those of a male are sterile. Ovarian eggs are produced and develop almost to the point of being transferred to the brood pouch, but their development then ceases and they disintegrate within the ovary.

The occurrence of a second sex-intergrade strain adds greatly to the interest and significance of such forms. Sex is again revealed not as a precise and definite state, not as an alternative condition, but as a purely relative condition.

Non-necessity or sexual reproduction in Cladocera.—In the last several reports I have referred to the significance of the fact that the lines of the various species of *Cladocera* continued reproducing parthenogenetically without apparent diminution of vigor. Such is still the case. The oldest lines of different species have now (September 1, 1917) been reproducing parthenogenetically in the laboratory as follows:

Table 6.

Species.	No. of strains.	No. of months in the laboratory.	No. of generations produced in laboratory.
Daphnia pulex	7	70	235 to 256
Daphnia longispina	3	46	151 to 175
Simocephalus vetulus	10	61	198 to 206
Simocephalus serrulatus	3	23	80 to 86
Moina brachiata	5	25	183 to 192

In spite of this long and continuous parthenogenetic reproduction the lines seem to be as vigorous as ever. No apparent need for sexual reproduction has manifested itself, for although males have appeared in response to the appropriate environmental influences, sexual reproduction has not occurred and the lines have continued parthenogenetic reproduction with undiminished vigor.

Sex in mucors.—Dr. Blakeslee reports that, in investigations on the common bread-mold, in which he was assisted by Mr. A. F. Schulze, some facts of interest were discovered relating to the distribution of the two sexual races in nature and to the differences between them.

THE INHERITANCE OF GERMINAL PECULIARITIES.

FLOWERING PLANTS.

Investigations on the flowering plants have been continued by Dr. Blakeslee along the lines reported on last year.

In the yellow daisy (*Rudbeckia hirta*) added evidence has been accumulated in regard to the inheritance of self-sterility and self-fertility and the effects of inbreeding which tends to bring about incompatibility between sibs, reduced germination, and dwarfed and weakened offspring. It has been definitely established that there are two types of variants with yellow cones. The one turns black, the other bright crimson, with KOH, but they are alike in outward appearance. When these two types are crossed they throw purple cones in the F_1 generation, and in the F_2 the two yellow types reappear. A repetition of crosses grown in the garden last year indicates that one of our original crosses on wild plants resulted from off pollination and that we have in hand only two instead of three genetically distinct types of yellow cones as reported last year. Investigation of doubling now under way indicates that this character is extremely complex.

The work on jimson weeds (*Datura stramonium*) has been extended, and a number of new mutants discovered. One called "Globe" reported upon last year we have grown for several generations without being able to obtain a line which breeds pure for this character. The "Globe" plants can be recognized in the seed-pans and extensive sowings are soon to be made of pedigrees from this mutant which will not be grown to maturity. It is suggested from work already done that the mutant character is transmitted through the female and not through the male parent.

The type with spineless capsules, slit corollas, and lacerated leaves which was grown last year and provisionally classed as a dominant character has been investigated in some detail. The character-complex appears first on the later branches of slightly over 1 per cent of the plants in the field from five different sources. When the character is well expressed the stamens contain no pollen. The seeds secured

by pollination with normal plants throw offspring with about 79 per cent showing the peculiarity in the seedling stage. The proportion of abnormal plants depends roughly upon the strength of the abnormality in the capsule producing the seed. In a single instance good pollen was obtained from an abnormal plant and crosses showed that the abnormality is transmitted through this pollen. Normal plants grafted on abnormal plants take on the complete abnormal complex, as shown in the new leaves, flowers, and fruits which subsequently develop. The abnormality, therefore, looks like a bacterial disease. Inoculations, however, with expressed juice of the abnormal plants have so far failed to infect normals.

One of the mutations in the jimson weeds is of considerable interest, since it suggests the way in which a new species having once originated by mutation may be able to establish itself as a perfectly distinct form without intergrading with the parent species alongside which it is growing. The mutation in question is perfectly self-fertile and the sibs in its offspring are fertile *inter se* and with the original parent mutant. Neither the mutant nor its offspring (with doubtful exceptions) have been found capable of crossing with any of the several different lines that we have under cultivation.

In *Portulaca*, a dwarf mutant has been found which apparently acts as a Mendelian recessive, but which occasionally produces branches reverting to the normal type which are heterozygous for the dwarf character. Other vegetative segregations as well as doubling and color types of flowers in this species are being studied. Doubling in *Portulaca* seems to be a Mendelian dominant, the homozygous full doubles having the stamens and pistils so strongly transformed into petals that they rarely set seed, the heterozygous semi-doubles segregating according to expectation into full doubles, semi-doubles, and singles.

Doubling and self-fertility are under investigation in *Helianthus*.

Verbena is being investigated for color-characters and self-fertility. The pollen of individual plants may be largely imperfect. The number of seeds produced by bagged clusters seems roughly proportionate to the amount of good pollen produced by the flowers.

For a number of years Dr. Blakeslee has been growing pure lines of the adzuki bean (*Phaseolus angularis*) largely for class demonstration purposes. The species is largely grown in Japan for human food and is reported to be, next to the soy bean, the most prolific yielder of seed of the leguminous plants in cultivation. In the vicinity of Washington, D. C., it gives about twice the yield of the common navy bean. Unlike the soy bean, which has to be prepared commercially, the adzuki bean may be used in the home in the same way as is the navy bean. Its high yield and its freedom from the so-called rust which has ruined the bean industry in certain regions suggested the adzuki as a valuable plant to

introduce for human food and improve by scientific breeding. This Department has been glad that the services of Dr. Blakeslee and his assistants could be offered to the Government for work with this new Japanese bean and the problem has been accepted by the National Research Council as "an emergency war-research problem." It is proposed as rapidly as possible to develop a stock of seed from the most prolific lines and get the beans on the market and in the meantime to combine, if possible, the desirable characters of size and color of seed, yield per acre, and early maturity. Dr. C. V. Piper, Agrostologist of Forage Crops Investigations of the Bureau of Plant Industry, U. S. Department of Agriculture, who has been growing different races of adzuki beans for several years as a possible forage crop, has kindly sent us seed material of desirable races for starting the hybridization work. Much of the hybridization work must be done in the greenhouse in order to gain an additional generation a year.

Since the last report Dr. Blakeslee has grown approximately the following numbers of plants in garden and greenhouse:

TABLE 7.

	Garden.	Greenhouse only.		Garden.	Greenhouse only.
Datura.......	9,400	11,700	Helianthus..	1,000	......
Rudbeckia....	14,000	......	Portulaca....	3,000	3,000
Verbena......	700	200	Adzuki beans	About 1.5 acres.	......

Dr. Harris has undertaken systematic tests of the productivity of lines of navy beans as Dr. Blakeslee has of the adzuki beans. He is engaged on experiments upon the technique of variety testing, the theory of which is in especial need of investigation.

Tetracotyledonous beans.—In an extensive series of bean seedlings Dr. Harris has found some with more than the normal number of 2 cotyledons, and these have founded 7 lines which yield exclusively abnormal offspring, of which 7,602 were produced in 1915. The abnormalities, which are probably physiologically related, are: more or less fasciated axis; divided axis; cotyledons varying in number from 2 to 7, 4 being the commonest condition; primordial leaves varying in number from 1 to 14, with a mode at 4; foliar ascidia. It appears that the correlation between number of leaves and number of cotyledons in this abnormal series is low, only about 13 per cent. The field studies on the beans are being supplemented by various intensive physiological investigations. Work on the histology of the normal and teratological seedling in relation to the problem of variation correlation and selective death-rate has been begun by Dr. John Y. Pennypacker.

HEREDITY OF ATAXIA AND DEFECTIVE PLUMAGE IN PIGEONS.

These two defects have been studied together in the same stock of common pigeons by Dr. Riddle, and the fourth generation has now been obtained. The ataxia arose in a single individual, a female. The defective plumage ("scraggliness") has rarely appeared in our stock. It has been bred from the only adult living bird (a male) of this kind which we possessed. The fact is to be noted here that both these rarely occurring defects have been perpetuated quite undiminished to the fourth generation.

HEREDITY IN MAN.

Stature.—The Director, in cooperation with the Eugenics Record Office, has completed a study of inheritance of human stature, which has been published in Genetics. Stature has long been a classical object of investigation, largely because it is so readily measured. Thus, in 1889 Galton published his studies on stature in parents and children and their interrelation. This led to Professor Karl Pearson's remarkable series of investigations "Mathematical Contributions to the Theory of Evolution" that founded the biometric school, which has left its imprint on biology, though it has proved disappointing in its assistance to the study of heredity. Though stature is the end-result of a number of independently varying elements, still, because of facts that determine growth as a whole, and because the length of the separate segments of stature are separately inheritable, it is possible to find some law of inheritance of the trait.

The present study was made on data derived from 3,298 children, their 1,738 parents, and a number of grandparents, uncles, and aunts. A large proportion of these were especially measured at their homes in various parts of the country. The hypothesis is supported that while short parents tend, on the average, to have short children, they may, and frequently do, carry germ-cells which lack the shortening factors; on the other hand, all of the children of tall parents are tall. Consequently the offspring of two very short or short parents are more variable in stature than the offspring of two very tall or tall parents as 2.4 is to 2.2. Also, whereas the offspring of two very short or short parents tend, on the average, to be less extreme than the parents, this is not true of the offspring of two very tall or tall parents.

Not only is stature as a whole inherited, but also, and even more clearly, each segment of stature, such as neck, length of torso, thigh, and foreleg; and the inheritance of the length of these segments follows the same law as does stature as a whole. An interesting by-product of this study is that persons of similar stature tend to marry each other, and the more extreme their stature the more particular are persons in this respect. Among 869 matings that of a very short man to a very

tall woman occurred only once, or one-tenth the expected number of times, while the marriage of a very tall man to a very short woman did not occur at all.

Hereditary traits of naval men.—The Director, assisted by Miss Mary T. Scudder, has analyzed the juvenile and family history of naval officers representing 65 families and including over 100 naval officers of various grades. The result has been the formulation of a new method which may be utilized in the selection of naval officers, namely, the consideration of the facts of juvenile promise and family history. It is found that naval officers are of different types; there are naval fighters (like Nelson, Farragut, Porter, and Cushing), naval explorers (like Sir John Franklin, McClintock, and our own Wilkes), naval inventors (like Dahlgren), naval diplomats (like Hornby), and so on. To consider the fighters only, one finds nomadism, love of the sea, hyperkinesis, and absence of fear practically universal, even at a very early age. The hyperkinetic tendency shows in either father or mother; if in both it tends to be exaggerated in the son. The factors for the nomadic and adventurous traits usually come from the maternal germplasm only, though, in consequence of the fact that young naval officers frequently marry young women of naval stock, the traits may be shown in both sides of the house. It is concluded that the strong inclination toward the sea depends upon a recessive factor.

HEREDITY IN SHEEP AND POULTRY.

The experiments on heredity of twinning, multinippling, and production of a superior strain in sheep have been continued. At the station 22 lambs were born from 13 mothers, not quite so good a record as last year. The cooperative sheep experiment with the New Hampshire Experiment Station is being continued. A paper on "Family performance as a basis for selection in sheep" was published conjointly with Mr. E. G. Ritzman, animal husbandman at the New Hampshire station. Progress is being made with the poultry strains. During the year 338 chicks were hatched, mostly of "new buff" and "bareneck" strains.

EXPERIMENTAL PRODUCTION OF VARIATIONS.

COLORATION OF CAVE SPECIES IN SUNLIGHT.

Cave-inhabiting amphipods are without pigment and appear of an opaque white, nor will they gain pigment when exposed to sunlight. The young of one species from the caves of southern Indiana have been reared by Dr. Banta in daylight and gained a brownish-pink coloration. This color does not depend on chromatophores, nor does it lie in definite granules. Its significance remains undetermined, though it is clear that the light has induced some physiological change that leads to the production of a diffuse pigmentation.

FORCING PIGMENTATION IN ALBINOS.

Dr. Riddle, in collaboration with Mr. Victor K. LaMer, has been able to induce the formation of melanin pigment in the choroid of a species of dove in which such pigment is not ordinarily produced. They show that free oxygen is necessary for the process.

PHYSIOLOGY OF REPRODUCTION.

EGG-PRODUCTION AND SKIN-COLOR IN FOWLS.

Dr. Blakeslee, who discovered two or three years ago that yellow pigment on the ear-lobes and shanks of White Leghorn fowls was inversely correlated with fecundity, has published a fuller paper, with statistical analysis by Dr. Harris, on this subject. It appears that the percentage of yellow (as measured by the color top) in the ear-lobe during October is closely inversely correlated with the mean annual egg-production of any bird. The correlation is 0.55. The result is of great practical importance, since by it one can tell in October without trap-nesting which birds have been the heaviest layers during the past year. Birds showing only 10 to 20 per cent of yellow in their ear-lobes in October will have laid at the end of the following year on the average about 185 eggs; those exhibiting 55 to 65 per cent yellow will have laid on the average only about 130 eggs. This result is believed to be due to the circumstance that the growth of the eggs in the ovary abstracts yellow pigment from the body-tissue, or precludes its being deposited there. In any case the discovery, now abundantly demonstrated, is of great practical, and not a little theoretical, importance.

RELATION BETWEEN NUMBER OF OVULES PER POD AND FERTILITY IN BEANS.

A study of over 150,000 pods of beans was made to determine the degree of relationship between the number of ovules per pod and the capacity of the pod for maturing its ovules. The conclusion is that there is a negative relationship between these two qualities such that the greater the number of ovules the smaller the proportion that will develop into seeds. The correlation is not a very close one, however, being of the order of about 2 per cent. This investigation and that recorded in the following paragraph were made by Dr. Harris.

RELATION BETWEEN NUMBER OF PODS PER PLANT AND INDIVIDUAL SEED-WEIGHT IN BEANS.

From 15,897 bean plants 78,975 seeds were weighed and it was determined that uniformly in each of 27 cultures there was a positive correlation between the number of pods on the plant and the average size of the beans produced. The size of the correlation varied from $+0.005$ to $+0.339$, with a mean of 0.159 ± 0.012. This result agrees with others secured earlier that permit the conclusion that, on the average, the larger the number of pods on the navy-bean plant the

greater the number of ovules and of seeds per pod and the greater the average weight of the seeds.

RELATION BETWEEN SYMMETRY AND FECUNDITY.

The relation between symmetry in distribution of ovules in the bean-pod and the average number of seeds formed has been studied by Dr. Harris in navy beans. It appears that in pods with unsymmetrically placed ovules fewer of them, on the average, form seeds than in pods with symmetrically placed (even) ovules.

OTHER INVESTIGATIONS.

VEGETABLE SAPS.

By means of the method of measuring osmotic pressures of vegetable saps elaborated by Gortner and Harris, Dr. Harris and Mr. John V. Lawrence have made an interesting series of comparative investigations into the concentration of saps.

First, they have studied the relation between the osmotic concentration of leaf sap and height of leaf insertion in trees and have found that the concentration (as determined by the freezing-point-lowering method) increases from lower to higher levels, and it seems probable that it is by virtue of this increased concentration at higher levels that sap rises to the higher levels.

Second, they have considered the relation of concentration of sap of the whole plant to environmental conditions. Thus they find that about the Desert Laboratory at Tucson the plants of the arroyo or sandy wash show the lowest osmotic values, sometimes only half of those of related species growing in other habitats. Next higher in sap concentration came the plants of Pima Canyon, then those of the rocky slopes; next those of the mesa-like slopes, and, highest of all, those of the salt spots, where the osmotic values are 12 to 71 per cent greater than those of plants from the other habitats studied. It appears, also, that the sap concentration diminishes in the successive terms of the series—trees and shrubs, half-shrubs, perennial herbs, and winter annuals. In the Jamaican coastal deserts a similar high concentration of cell-sap is found. In sharp contrast with the condition in the deserts, the vegetation of the rain-forest of Jamaica is characterized by low sap-pressure, the concentration of the fluids of the latter being less than half that of the former.

Again, they have shown that phanogamic plants (Loranthaceæ), parasitic upon other plants, have, in general, a higher osmotic sap-pressure than their hosts. It is apparently by virtue of such higher concentration that they are able to steal fluids, by osmosis, from their hosts.

Dr. Harris, working with Mr. Wilson Popenoe, has been able to show that of three types of the tropical fruit avocado, whose cultivation is now being conducted in Florida, the Mexican type has a more concen-

trated sap, with lower freezing-point, than that of the West Indies, and this fact, doubtless, accounts for the circumstance that the Mexican type is the hardier. Dr. Harris suggests that a knowledge of the freezing-point-lowering of the sap of a species of plant would be of some service in predicting ability to withstand cold.

A study of the remarkable marine shrubs known as mangrove trees shows that some of them have a high internal pressure—up to 50 atmospheres or possibly more. Certain mangroves which live in nearly fresh water have only half of that concentration. Probably it is this capacity for developing a high sap-concentration that has permitted the mangrove to live in salt water.

TOXIN OF BREAD-MOLD.

The investigation of the toxicity in the common bread-mold (*Rhizopus nigricans*) carried on in our laboratories in cooperation with the Bureau of Chemistry of the U. S. Department of Agriculture has been brought to a close. An extended report upon the mycological findings has been written up and is now in the hands of the Bureau of Chemistry at Washington ready for publication. Mr. A. F. Schulze, who was employed here by the Bureau of Chemistry as Dr. Blakeslee's assistant in this work, has been called to a model food-preserving plant in Brooklyn.

BIOMETRIC MISCELLANY.

Dr. Harris has analyzed biometrically certain data on liability of potatoes to disease. The most important conclusion is that varieties of the potato which show more than the average amount of injury by one disease will, on the whole, show more than the average injury by another disease; accordingly, "to a considerable extent, susceptibility to disease is general rather than specific."

Dr. Harris has reviewed certain extensive data on the number of nipples in litters of pigs. He finds the variability in this number greater in males than females, as 1.48 is to 1.28. Also the correlation in nipple number between pigs of the same litter is 0.305 ± 0.019. This, as Harris justly concludes, is evidence of a strong inheritance of nipple number. Still it would be more significant to calculate the correlation inside the litter of some marked excess over or deficiency under the modal number.

GEOPHYSICAL LABORATORY.

Arthur L. Day, Director.

The present calendar year has been a most important one for the Geophysical Laboratory and for the problems which it seeks to develop. It has proved important first because in this year we have been able to demonstrate for the first time that rock formation in which volatile ingredients play a necessary and determinative part can be completely studied in the laboratory with as much precision as though all the components were tangible solids or liquids. When tiny globules of water or carbon dioxide are found inclosed within mineral crystals undisturbed since the time of their formation, we know that such volatile matter was present and must have had an active share in the formation process in nature; in fact, mass for mass it must have been incomparably more active than the silicates. We know also that many of the mineral groups could not have taken their present form without the aid of substances of which only significant traces now remain. But we have not hitherto been able to perform such an operation in full quantitative detail up to and beyond the critical temperature and pressure of the volatile component (water), nor have we been able to infer from existing laboratory data just how such volatile ingredients participate in silicate reactions of this kind at high temperatures and appropriate pressures. The present work has therefore served to advance our problem very materially and to develop its possibilities in a way to justify the fullest confidence in its future.

I shall reveal no state secret to-day in saying that there was once a time when our confidence in the capacity of physics and chemistry to solve these geological problems was not shared by all geologists. There were some who were inclined to view with considerable apprehension the vast ramifications and complications of natural rock formation as a problem impossible of adequate solution in the laboratory. It is therefore a matter of satisfaction to all those who have participated in these efforts to see the evidences of this apprehension disappearing gradually as the work has progressed. A careful appraisement of the situation to-day, after ten years of activity, reveals the fact that the tangible grounds for anxiety about the *accessibility* of the problems which we then confronted are now for the most part dissipated. It has been adequately demonstrated that the temperature conditions which prevailed during the formative period upon the surface of the earth are well within reach of known methods of accurate measurement; that the effects of pressure as a factor in the formation process are insignificant compared with those of temperature, except where volatile ingredients are concerned; that the established generalizations

regarding solutions and the laws of physical chemistry apply broadly to silicate solutions as well as elsewhere; that the multiplicity of participating substances is not a prohibitive difficulty when these are appropriately grouped for study; and now, finally, that the fact that some of the substances which participated in the formation process were volatile and disappeared in part from the system in the process of its development is no longer an absolute bar to the competent study of such systems. All this was necessary, and with appropriate detailed development may be expected to prove sufficient for the competent study of rock formation with its allied problems and applications, which was the purpose of the founders of the Geophysical Laboratory.

The second direction in which the interests of this laboratory have advanced materially during the year is in the progress of volcano study. Perhaps for the first time in the history of volcano observation, laboratory-trained men have stood upon the brink of an active volcano basin, fully equipped to measure the temperature distribution prevailing deep down in the boiling lava at their feet and to collect appropriate samples both of the liquid and gaseous ingredients which through their interreaction so largely determine the character of volcanic phenomena. The materials so collected still remain to be studied and no inference at this time can properly forecast the conclusions which will be reached as a result of these studies, but the opportunity presented this year was a rare one and the fact that trained men and appropriate facilities were on the ground to take advantage of it forms one of the bright pages in the history of this elusive science. It will be recalled that volcanoes offer the only opportunity now remaining to science to study the phenomena accompanying the formation of igneous rocks in nature, and by far the greater portion of these must remain entirely inaccessible to man because of the violence of their activity.

During the present season an opportunity was also afforded to this laboratory, through the courtesy of the National Geographic Society, to be represented upon the advisory committee in charge of its exploring expedition to Mount Katmai, the great Alaskan volcano which exploded with extreme violence in 1912, and to provide equipment for the collection of samples from the gaseous emanations and the salts deposited thereby. These were collected with great care and considerable hardship by Professor Robert F. Griggs, leader of the expedition, and Professor J. W. Shipley, its chemist, and are on their way to Washington at the time of writing.

Volcano studies in Italy, which are in charge of Mr. Frank A. Perret, have suffered somewhat from limitations placed upon the movements of foreigners and the use of instruments because of the state of war. Notwithstanding these, Mr. Perret has been able to make occasional observations of Vesuvius and has twice spent a night at the bottom

of its crater with the intrepid director of the Vesuvius observatory, Professor A. Malladra, securing valuable specimens of ejecta, observations of temperature, and nearby photographs of the activity now prevailing there. In the laboratory Mr. Perret has also developed a remarkably compact microphone system and recorder for studying the subterranean sounds of volcanoes with the ultimate purpose of correlating these with consequent surface phenomena, if it shall prove practicable to do so, and thus to permit the accurate prediction of eruptions. Of course a systematic study such as will be necessary before confident predictions can be made must cover a considerable time, but a vast saving of human life may result from it if successful. Mr. Perret's report of the work of the year will be found on a later page.

The third matter which marks the present year for special distinction in the history of this laboratory is a direct consequence of the European war. Since April last the staff and resources of the laboratory have been concentrated in large degree upon the vital problem of producing within the United States, from American materials, both a quality and a quantity of optical glass adequate for national needs. At the time of the entrance of the Geophysical Laboratory into this field of activity the quality of optical glass available was admittedly unsatisfactory; it contained striations indicating an absence of homogeneity, "stones" (undissolved fragments of the pot or the glass charge) were frequent, and the waste in cutting out pieces suitable for optical instruments was very great. Moreover, the transparency of all the American glasses was altogether inferior to that of foreign make regularly used before the war because of impurities in American raw materials which had not at that time been identified.

In confronting this situation the Geophysical Laboratory was obliged to take into account a dominant factor not directly connected with the art of glass-making, namely, the immediate need for a quantity of glass at least tenfold greater than normal requirements. Obviously, therefore, there was no time at the moment for a thorough investigation of details through which the quality of the glass could be greatly improved. The problem was rather to scour the country for the best raw materials available in adequate quantity and to concentrate effort to manufacture these materials in the shortest possible time into tolerable glasses of the various types considered imperatively necessary. This was accordingly the course pursued.

Of the difficulties and details developed by the problem, it is not possible to give an adequate account in a report of this kind. Suffice it to say that with a group of 20 scientifically trained men, all skilled in handling silicate solutions at the temperatures required for making glass, and familiar with the control of most of the factors in the problem, it proved practicable to make rapid progress and in June following, after two months of concentrated effort, the gross production of glass

by the leading American manufacturer had been increased from 15,000 to 28,000 pounds per month and its quality improved to such an extent that rejections by government inspectors became comparatively rare. The output will probably reach 45,000 pounds gross during the month of October, and if necessary can now be increased still further.

Now that the output has reached a magnitude such that an adequate supply of suitable glass is assured for national needs, the attitude of this laboratory toward the problem has changed somewhat. Instead of straining every nerve to increase gross production, many refinements are now being effected of a character to bring the quality of the glass to a higher level. Of these a more detailed account will be published in due time.

Of the quality of the glass now produced, it may be said that the present product is homogeneous and free from optical imperfections except in so far as "stones" still occasionally interfere to compel wasteful cutting of otherwise excellent blocks. These are due at the moment solely to unsuitable clay melting-pots, granules of which are easily detached and remain in suspension in the glass. It is easy to see that in a charge of optical glass weighing 1,000 pounds or more and requiring to be stirred (as other glasses are not) for several hours to produce the desired homogeneity, the pot wall, always more or less soluble, may contribute grains which can not be eliminated. Moreover, glass pots after manufacture require some four months to dry before they can be used, and the pots now in use by the trade were neither developed nor intended for optical glass. An appropriate study of this problem will necessitate improvements in the pot-maker's art which are no less extensive than those which confronted the glass-maker. This phase of the investigation has already been actively taken up by Dr. A. V. Bleininger, ceramic chemist of the Bureau of Standards (Pittsburgh), who has given assurance that an early and adequate solution is near.

The second chief problem which confronts the glass-maker is the large absorption of light in American-made glasses compared with the foreign glasses hitherto available. Without entering upon unnecessary detail, this has been shown to be due primarily to the iron contained in all the raw materials from which American glasses must be made. In so far as the ingredients of the glass are concerned, this difficulty has already been met through the cooperation of the United States Geological Survey in seeking suitable sources of glass-sand and of chemical manufacturers in purifying their output. There still remains, however, the disagreeable fact that American pot clays show some 2.5 times the iron content of the European pot clays, in consequence of which the solution of as much as 1 millimeter of the pot wall in the melting glass will multiply the iron content of the glass

by 4. The correction of this limitation therefore also devolves upon the pot industry rather than upon the glass-maker.

Briefly, then, it has proved possible, in rather less than six months, to produce optical glass from American materials in all the required varieties and at a rate sufficient to meet current requirements. The quality is also adequate for the present emergency. Of the limitations which still confront us, none at the moment appears insurmountable, though the production of melting-pots suitable for optical glass is a serious problem which may require considerable time for its solution. It is our present purpose, with the approval of the Trustees of the Institution, to continue the investigation until the United States shall be entirely independent of foreign sources of supply for optical glass.

The remark has sometimes been made by casual observers that the work of the Geophysical Laboratory, of all the departments of activity of the Carnegie Institution of Washington, lies farthest removed from the practical needs of everyday life. So long as the earth remains stable under our feet, it is sometimes deemed to be a work of supererogation to inquire closely into the details of its formation. In so far as this view is real and not uncommonly met with, it will not be accounted satire to call attention to the fact that the Geophysical Laboratory was the first of the departments of the Institution to be called to meet a practical emergency precipitated by war. Perhaps it is even a matter of pardonable pride to all the members of the laboratory staff that through the experience gained in their regular activities, and in these alone, they have been enabled, in cooperation with willing manufacturers, to reach an extraordinarily rapid and successful solution of so difficult a problem as the production of optical glass and to develop processes, hitherto secret, to the point of successful, large-scale manufacture, within the short period of a few months.

REPORT ON VOLCANO STUDIES AT NAPLES. (By Frank A. Perret.)

A brief account of the volcanic research work accomplished during the year must again be preceded, in simple justice, by a reference to the difficulties incident to the still continuing state of war—difficulties which tend to increase rather than diminish, and which must be imagined rather than described. It is no exaggeration to say, however, that, in spite of all, much has been done, and that along lines which, if not those most spectacular and showing immediate fruit, are by far the most important in the long run.

Field research.—This branch of the work is that which is hardest hit by existing conditions, which render traveling with instruments almost impossible and justified only by events of the greatest importance. From this point of view, it is perhaps fortunate that the Italian volcanoes have not led the volcanologist into temptation. With the exception of an explosive phase at the new northeast crater of Etna,

which lasted but 40 minutes, there has been nothing especially worthy of investigation at the Sicilian volcanoes. Field research has thus been limited to the neighborhood of Naples, *i. e.*, to Vesuvius, the Solfatara, etc.

A very interesting lava tunnel, of the intumescence type, has been found on the lava of 1858, and a description, with photographs by me, is soon to be published by Dr. Malladra. The interior was photographed by the light of an acetylene hand lamp with reflector, and shows the advantage of this form of artificial illumination over the ordinary flash-light. The picture shows a last little stream of pahoehoe lava which had flowed from the mouth on to the floor of the tunnel. There are also tree-molds, of small size, in that neighborhood.

Since April there has been no flow of lava in the crater of Vesuvius, but Dr. Malladra and I decided to make another descent on August 2, in order to compare conditions at the crater bottom with those prevailing at our last descent on August 4, 1916. The date was chosen on the basis of luni-solar positions, which influence was effective. Again the night was spent at the bottom of the crater, the entire stay being 15 hours. The eruptive conelet remains at the same height above the sea, but the crater bottom has been greatly filled up around it by lava which emanated from it and from a second conelet which has arisen over what, at our last descent, was a funnel depression near the base of the main conelet, and which we at that time agreed was destined to be a new vent. This second cone emitted several streams which were all of "aa" lava, and is now reduced to vapor emission. The lava in the conduit of the main eruptive conelet has returned to the ultra-liquid condition which was characteristic of the first year of the opening of the conduit (1913). At the time of our last descent there was sufficient viscosity for the formation of bombs. It now boils quietly within the cone, with now and then a throwing out of liquid fragments, of which samples have been sent to the laboratory. The general condition of the crater bottom is quite Hawaiian, with hummocks covered with lava splashes and some enormous intumescences which have lifted the crust of the floor to heights of 10 or more meters, showing a tendency to ramify from the main conduit of the eruptive conelet. The lava filling the great crater has now reached a sufficient height to make possible the initiation at any moment of an external lava flow of the slow type, such as characterized the last eruptive period (1875–1906) in the years 1881 to 1883, 1885 to 1886, 1891 to 1894, 1895 to 1899, and 1903 to 1904.

Conditions within the crater were bad as regards gas and photographs were made with the utmost difficulty, but through a process of redevelopment these have been brought out as strong and clear as any and the complete documentation has thus been successfully accom-

plished. No moving pictures were attempted, under such circumstances, although the complete apparatus was carried. Observations of importance, too numerous for mention here, were made during the stay within the crater.

A project has been set on foot to utilize the heat of the Solfatara by the generation of electric power for industrial purposes and I have been appealed to for advice and the making of some preliminary soundings. I have consented the more readily as the work will eventually involve deep borings which can not fail to increase our knowledge of conditions in the hidden portions of this volcanic vent. I have so far made borings to a depth of 6 meters. These tend to show the correctness of the hypothesis that the crater formerly contained a lake of boiling mud. The most striking thing revealed by these experiments is the extension of this stratum of wet clay at 100° C. over practically the entire area of the present floor at a depth of 1 meter. Even under the portions covered with vegetation the same temperature obtains and a new and powerful fumarole may be created at will in any place whatever. By placing a pipe so as to provide a conduit not destroyable by collapse of its walls, I have made fumaroles which are permanent. A syndicate for carrying out this project is in process of formation.

Laboratory work.—Much laboratory work has been done. Apparatus for recording upon wax cylinders the subterranean sounds of volcanoes has been brought almost to perfection. It was found that the commercial cylinders were unsuitable for this delicate work, and the Columbia Graphophone Company was appealed to to make up a quantity of the old, pure wax type. They have kindly done this, the Geophysical Laboratory has purchased them, and they have arrived here. The microphone itself has now been greatly improved, and a perfect little portable field outfit weighing less than a pound has been evolved. Several electrical and other instruments have been added to the laboratory equipment, and experiments initiated along various lines, such as the condensation of water vapor through nucleation, magnetic concentrating lens, volcano experiment models, etc. A dark-room outfit has been added, as mentioned below.

Photography.—Existing conditions have greatly affected this branch of the work, not only directly by the difficulty of obtaining good material and its increased cost, but by the necessity of personally losing time in printing, washing, etc., which might be employed more profitably. The closing of the studio of G. Sommer & Son and the removal of the family to Rome has been compensated only partially by the instalment of a little dark-room outfit here, which permits the development of negatives and the making of prints but not enlargements.

Publicity.—A popular lecture on "The study of the world's volcanoes, and what it reveals" was given at Naples for the benefit of the Anglo-American Church. The lecture was illustrated with colored

slides and much interest and some surprise were shown at the presentation of the world's volcanism as a constructive rather than destructive agency. Papers are begun on the subjects of the great Vesuvius eruption of 1906, the Stromboli outbreaks of 1907, 1912, and 1915, the recent descents into the crater of Vesuvius, the influence of open and closed volcanic conduits on external eruption.

Astronomy.—The telescopic study of the lunar craters—begun with the 5-inch reflector—just before the war has been interrupted by the inadvisability of using the telescope on the terrace during present conditions, but the total lunar eclipse of July 4 was an event for which to take risks, and perfect weather gave opportunity for very good observation. My notes, in French, are to be published in the Bulletin of the Société Astronomique de France. One of the observed effects brought out a reference to the phenomenon of the "flashing arcs" observed by me at Vesuvius and Etna. From some recent observations at the front in France, it would seem that sound waves from heavy cannonading have, under certain conditions of lighting, been visible.

PUBLICATIONS.

Brief reviews of the papers published by members of the Laboratory staff during the current year follow:

(1) Some aspects of recent high-pressure investigation. John Johnston. J. Franklin Inst., 183, 1–32 (1917).

There has been an increasing realization of the necessity of investigating the behavior of substances throughout a wide range of conditions—temperature and pressure especially—if we are to increase the scope of our present chemical generalizations. Considerable work has now been done in the high-temperature field, but until recently very little has been definitely ascertained as to the precise effects of high pressures. Pressure and temperature are completely analogous as variables; experiment has shown that in general a pressure change of 1,000 atm. will produce no larger effect than a temperature change of a few degrees—a difference which, of course, depends only upon our system of units.

Pressure raises the melting-point of solids (with two known exceptions, ordinary ice and bismuth), the change being successively less with each increment of pressure; but there is no evidence at all for a maximum melting-point or for a critical end-point. Indeed, all evidence indicates that by the application of *sufficient* pressure gases would be transformed to solids, a conclusion which is in harmony with that reached on other grounds that the interior of the earth is solid. The effect of pressure upon solubility, and upon condensed systems generally, is small; when a gaseous component is present the effect may be very large by reason of the great increase in concentration of the gas produced by the pressure. But many of the effects which have been attributed to pressure are not due to it alone, but often to the high temperature chiefly, the pressure being merely a subsidiary influence; and in such discussion one must always be careful to distinguish between uniform pressure and non-uniform compression, as the latter will produce effects very different from those of the former.

Many physico-chemical determinations may now be made with just as great accuracy at high pressures as under ordinary conditions. Apparatus suitable for this purpose has now been developed in several laboratories; some of the apparatus which we have used is illustrated and briefly described.

(2) A table for linear and certain other interpolations on spectrograms. H. E. Merwin. Am. J. Sci. (4), 43, 49–56 (1917).

The usual formulas for interpolating spectrograms make distance a function of wave-length and require the solution of at least a second-degree equation. If, however, distance is made a function of the dispersion of a prism intermediate between glass and quartz, then by means of a table and a linear equation distance can be obtained as a function of wave-length.

(3) Crystallographic and optic properties of mannoketoheptose and of the osazones of mannoketoheptose and mannoaldoheptose. F. E. Wright. J. Biol. Chem., 28, 523–526 (1917).

Measurements of the crystallographic and optic constants of crystals of mannoketoheptose prove that they are monoclinic-hemimorphic in character (digonal polar type); etch figures produced by immersing the crystals for 10 seconds in alcohol are in accord with this type of symmetry. The osazones of mannoketoheptose and of mannoaldoheptose were prepared and yielded, so far as could be determined, the same crystal substance which appears in yellow needles and radial aggregates of fairly high refractive index and of medium birefringence. Characteristic of this substance are its abnormal interference colors which range from orange-yellow to blue-green and are the result of remarkably strong dispersion of the bisectrices and of strong spectral absorption of the blue end of the spectrum.

(4) The sodium-potassium nephelites. N. L. Bowen. Am. J. Sci. (4), 43, 115–132 (1917).

This paper gives the results of an experimental investigation of the binary system $NaAlSiO_4-KAlSiO_4$. The soda compound occurs in two enantiotropic forms, nephelite and carnegieite, with an inversion point at 1248°. The high-temperature form, carnegieite, melts at 1526°. The potash compound shows two forms, kaliophilite, isomorphous with nephelite, and an orthorhombic form with twinning analogous to that in aragonite. The orthorhombic form is apparently stable at temperatures above 1540° and melts in the neighborhood of 1800°.

The potash compound has a eutectic with carnegieite at 1404°. With nephelite it forms an unbroken series of solid solutions. It is concluded therefore that $NaAlSiO_4$ and $KAlSiO_4$ are the fundamental molecules of natural nephelites. But, in addition to these, nephelites contain variable amounts of plagioclase in solid solution, the plagioclase varying from albite to anorthite, the latter accounting for the lime content and the former for the excess silica of the natural mineral. The composition of nephelite should therefore be expressed in terms of the four molecules $NaAlSiO_4$, $KAlSiO_4$, $NaAlSi_3O_8$, and $CaAl_2Si_2O_8$. Reference is made to the petrogenetic importance of the occurrence of the last two (plagioclase) molecules in nephelites.

(5) Some problems of the oxides of iron. Robert B. Sosman. J. Wash. Acad. Sci., 7, 55–72 (1917).

The oxides of iron present problems of great importance to chemistry, physics, geology, and biology. Among the chemical problems are: The solubility of oxygen in iron, the relations of FeO to iron and to Fe_3O_4, the internal structure of the solid solution system Fe_2O_3-Fe_3O_4, the cause of the peculiar

form of the dissociation-pressure curve of this system, and the relation of adsorbed oxygen to Fe_2O_3. The physical problems are of special interest because of the variety of magnetic properties exhibited by iron and its oxides; the nature of magnetic inversions and of polymorphism in general, and the bearing of the properties of the magnetic form of Fe_2O_3 on this problem are discussed. It appears that the magnetic properties of iron and its compounds are intimately connected with the spacing and arrangement of the iron atoms and that the inversions may occur within the atom itself. The origin of magmatic and pneumatolytic ores is one of the geological problems now attracting attention; magnetic studies are expected to throw light on this question. The genesis of the sedimentary iron ores is a problem in colloid chemistry, complicated by the question of the activities of the so-called iron bacteria.

(6) A method for the determination of dissociation pressures of sulphides, and its application to covellite (CuS) and pyrite (FeS_2). E. T. Allen and Robert H. Lombard. Am. J. Sci. (4), 43, 175–195 (1917).

A new method has been devised for the determination of dissociation pressures at comparatively high temperatures in cases where mercury gages can not be used. It is intended especially for sulphides. It depends in principle upon balancing the dissociation pressure of the sulphide by the vapor pressure of sulphur at a known temperature; the pressure is not directly measured. The method applies to other compounds than sulphides provided there is a single volatile dissociation product which does not attack glass (or quartz glass) and which condenses at accessible temperatures. The method can not be used above 1100° to 1200°. By it the dissociation pressure curves of covellite (CuS) and pyrite (FeS_2) have been determined from about 1 mm. to 500 mm.

The method's chief advantage is that the equilibrium is approached from both directions and the experimenter is therefore not liable to be deceived by false equilibria; it has the disadvantage of being slow and is inaccurate at pressures much above an atmosphere. It was devised for the investigation of complex sulphide systems where the dissociation pressure is a factor in stability that can not be neglected. There seems to be no reason why it should not find a broader application to other systems of similar characteristics.

The method also supplies a convenient means for the synthesis of sulphides the dissociation of which causes difficulty.

(7) The electrometric titration of zinc with ferrocyanide. F. Russell von Bichowsky. J. Wash. Acad. Sci., 7, 141–143 (1917).

In the course of the titration of a zinc salt with a ferrocyanide solution, the electromotive force of a polarized platinum electrode placed in the mixture, instead of decreasing with the addition of the reducing agent, at first increases, reaching a maximum usually just before the end-point. The conditions governing the position of this maximum have been studied and on this basis a theory is proposed to account for this effect and the similar effect noted by Forbes and Bartlett for the titration of ferrous iron with chromic acid. It is further proposed that the change of electromotive force of the platinum electrode be used as an end-point in the titration of zinc.

(8) The electrometric titration of zinc. F. Russell von Bichowsky. J. Ind. Eng. Chem., 9, 668–671 (1917).

This is a more extended account of the practical applications of the research outlined in the above abstract. The electrometric method for the analysis of zinc ores has the advantage that less care and time are required in the preparation of the solution for titration, the titration is quicker, and the end-point

much more positive and less affected by impurities than in any of the other methods. Complete details are given both of the method of preparing the ore for titration and of carrying out the titration.

(9) The iodometric determination of sulfur dioxide and the sulfites. John B. Ferguson. J. Am. Chem. Soc., 39, 364–373 (1917).

Before an extended investigation of volcanic gases could be carried out, some problems in analytical chemistry required solution, and in this paper are presented and discussed the results of an investigation of the various iodometric methods for the determination of sulphur dioxide and the sulphites. The object of this investigation was threefold: (1) To ascertain the limitations of the existing methods and procedures; (2) to determine the important sources of error; (3) to develop, if necessary, procedures suitable for general application.

Sulphur dioxide.—Of the methods considered, the excess iodine is suitable for the analysis of mixtures of either high or low sulphur-dioxide content; the Selby Smelter Commission method is suitable for mixtures of low sulphur-dioxide content; the Reich method gives only approximate results unless large samples are available; and the sulphite method must not be used without a correction factor. Two precautions are essential: (1) The gas sample must not come in contact with even a trace of moisture prior to reaching the absorbent; (2) the analyzing apparatus must be free from rubber connectors if mixtures containing 2 per cent or more of sulphur dioxide are to be analyzed; and rubber connectors would best be eliminated altogether. The excess iodine method is recommended.

Sulphites.—In the Treadwell method errors due to the oxidation of the sulphite solution arise from various sources and to eliminate them the following procedure is recommended: The solid salt is dissolved directly in an excess of an iodine solution containing sufficient hydrochloric acid, and the excess iodine determined with thiosulphite.

(10) The setting of litharge-glycerine cement. H. E. Merwin. J. Ind. Eng. Chem., 9, 390 (1917).

The setting of this cement is caused by the formation of acicular crystals growing in felty masses. The crystals have the composition $C_3H_6O_2.PbO$, and indices of refraction $\alpha=1.75$; $\gamma=1.80$; $\beta=1.84$. Larger grains of litharge become protected by coatings of the crystals and remain undecomposed for an indefinite time.

(11) A convenient form of autoclave. George W. Morey. J. Wash. Acad. Sci., 7, 205–208 (1917).

This paper contains a description of a new type of autoclave which has proven advantageous in the study of aqueous solutions at temperatures up to 300°.

(12) The ternary system H_2O-K_2SiO_3-SiO_2. George W. Morey (Chemical Study) and C. N. Fenner (Microscopic Study). J. Am. Chem. Soc., 39, 1173–1229 (1917).

The system whose study is described in this paper differs materially in several important particulars from practically all heterogeneous equilibria heretofore studied. Because of the presence of the volatile component water it is substantially different from the systems previously investigated in this laboratory, which were composed of non-volatile oxides and could therefore be treated as "condensed" systems. On the other hand, it differs from all aqueous systems previously studied in that the "solubility" or fusion relations have been studied under conditions of pressure and temperature far removed from ordinary

laboratory conditions; comparatively few binary systems of the type water-salt have been studied even up to their boiling-points and the interesting field of higher pressures and temperatures up to and including the critical point is almost untouched.

The ternary system H_2O–K_2SiO_3–SiO_2 has been studied over the temperature range 200° to over 1000°. The work comprises a determination of the composition and properties of the various stable solid phases which can coexist with solution and vapor within the above temperature range, of the composition of the solutions in equilibrium with the solid phases, of the change in composition of these solutions with temperature, and the approximate determination of the corresponding 3-phase pressures.

The chief experimental method used was an adaptation of the "quenching" method so extensively used in this laboratory for the investigation of dry melts. The anhydrous components were heated in closed bombs with water to the desired temperature, left until equilibrium was established, and quenched by plunging the bomb into water. If the charge was all liquid, microscopic examination of the solidified melt showed only glass; if the charge was a mixture of solid and liquid, the microscopic examination showed a mixture of crystals and glass. Depending on the result of the examination, more or less water was added to a second charge and the process repeated. By this means it was possible to fix the exact amount of water necessary to dissolve the material completely. The microscopic examination revealed the solid phase with which the liquid was in equilibrium; the amount of water in the liquid was determined from the difference in weight of the quenched hydrous glass and the anhydrous materials originally used, and the pressure was calculated by means of van der Waals's equation from the known amount of water in the vapor space at the temperature of the experiment.

The following are the compounds which occur: Silica, SiO_2; potassium hydrogen disilicate, $KHSi_2O_5$; potassium disilicate, $K_2Si_2O_5$; potassium disilicate monohydrate, $K_2Si_2O_5.H_2O$; potassium metasilicate, K_2SiO_3; potassium metasilicate hemihydrate, $K_2SiO_3.\frac{1}{2}H_2O$; and potassium metasilicate monohydrate, $K_2SiO_3.H_2O$.

In the binary system H_2O–K_2SiO_3, K_2SiO_3 is stable solid phase from its melting-point at 976° to the quadruple (transition) point, $K_2SiO_3.\frac{1}{2}H_2O$–K_2SiO_3 at 610°. The composition of the solution at this point is 0.345 mol H_2O, 0.655 mol K_2SiO_3; the corresponding pressure is about 9 atmospheres. $K_2SiO_3.\frac{1}{2}H_2O$ is stable from 610° to the quadruple (transition) point $K_2SiO_3.H_2O$–$K_2SiO_3.\frac{1}{2}H_2O$ at 370°; the composition of the solution is 0.53 mol H_2O, 0.47 mol K_2SiO_3, and the pressure, 6.2 atmospheres. At a temperature a little below 200°, $K_2SiO_3.H_2O$ is decomposed by H_2O.

In the binary system H_2O–$K_2Si_2O_5$, $K_2Si_2O_5$ is stable from its melting-point at 1041° to the transition (quadruple) point $K_2Si_2O_5.H_2O$–$K_2Si_2O_5$, at 410°; the composition of the solution at the quadruple point is 0.628 mol H_2O, 0.372 mol $K_2Si_2O_5$, and the corresponding pressure is 36 atmospheres. At about 280°, $K_2Si_2O_5.H_2O$ is decomposed by H_2O.

Potassium hydrogen disilicate, $KHSi_2O_5$, has a congruent melting-point at about 515°. It is decomposed by H_2O below 400°.

The various quintuple points, at which three solids can coexist in equilibrium with vapor and solution, are as follows: Quintuple point K_2SiO_3–$K_2SiO_3.\frac{1}{2}H_2O$–$K_2Si_2O_5$–L–V at 575° and a vapor pressure of 1.5 atm.; quintuple point $K_2SiO_3.\frac{1}{2}H_2O$–$K_2Si_2O_5.H_2O$–$K_2Si_2O_5$–L–V, 350° and 2.4 atm.; quintuple point $K_2SiO_3.\frac{1}{2}H_2O$–$K_2SiO_3.H_2O$–$K_2Si_2O_5.H_2O$–L–V, 300° and 2.7 atm.; quintuple point $K_2Si_2O_5.H_2O$–$K_2Si_2O_5$–$KHSi_2O_5$–L–V, at 405° and 32.3 atm.; and $K_2Si_2O_5$–$KHSi_2O_5$–SiO_2–L–V, at 510° and 12 atm.

The detailed results of the experiments are summarized in tables and also presented graphically by means of curves and photographs of solid models. The curves show the solubility relations in the binary systems H_2O–K_2SiO_3 and H_2O–$K_2Si_2O_5$, the isothermal polybaric saturation curves and the variation of vapor pressure of the solutions on each isotherm with the SiO_2/K_2O ratio in the solution, the isobaric polythermal saturation curves, and the P–T curves of the various monovariant systems, *i. e.*, systems containing four phases, in the ternary system. The solid models show the variation of the composition of the saturated solutions with temperature under the corresponding 3-phase pressures, and the variation of the composition of the saturated solutions with pressure at the corresponding 3-phase temperatures.

A short discussion of some of the theoretical considerations which govern the equilibrium relations in binary and ternary systems containing a volatile component is given and the proper use of the term "solubility" is discussed.

(13) Persistence of vents at Stromboli and its bearing on volcanic mechanism. Henry S. Washington. Bull. Geol. Soc. Amer., 28, 249–278 (1917).

In August 1914 six vents were active on the crater terrace of Stromboli. Examination of plans and illustrations in the literature (many of which are reproduced in the paper) shows that at least three of these vents have persisted in location as far back as 1768. Similarly, at Kilauea the main vent has persisted in location for about a century; and there is evidence of such persistence at some other volcanoes. This feature of volcanoes seems to have been previously unnoticed. Another notable feature of the Stromboli vents is that the three oldest of them open about 1,000 meters above sea-level near the upper edge of a precipitous scarp of that height. An analogous situation is true of some of the vents at Etna and also of one or two of those of Kilauea.

In the discussion of these and other features it is shown that such vents can not have originated through explosive agencies; but that their formation, situation, persistence in location, and other features, can best be explained by Daly's so-called "gas-fluxing hypothesis," which supposes a "blow-piping" of narrow, vertical vents through the superjacent rocks by gases derived from the magma in its reservoir below and which are heated and kept hot by chemical interreactions.

(14) The equilibrium between carbon monoxide, carbon dioxide, sulfur dioxide and free sulfur. John B. Ferguson. Proc. Nat. Acad. Sci., 3, 371–374 (1917).

In this paper is presented a preliminary summary of the results of an extended research on the equilibrium between carbon monoxide, carbon dioxide, sulphur dioxide, and free sulphur at high temperatures. These gases react according to the equation $CO+\frac{1}{2}SO_2 \rightleftarrows CO_2+\frac{1}{4}S_2$, and this reaction is one of the chief gas reactions involved in volcanic activity. It has great importance also from the fact that from a study of it the free energy of sulphur dioxide, a quantity indispensable to a proper study of the chemistry of the sulphur compounds, may be obtained directly.

Temp. absolute.	I
1271°	3.88
1273	4.12
1273	3.94
1277	3.85
1458	3.97
1463	3.96
1463	4.00

The character of the results presented may best be shown by the accompanying table, which gives the various values for the thermodynamic constant I derivable from the equilibrium constants obtained.

From the above data the free energy changes under standard conditions ($\triangle F_{298}$) have been calculated and are given below:

$CO+\frac{1}{2}SO_2=CO_2+\frac{1}{4}S_2 \quad \triangle F_{298}=-22529 \qquad S_R+O_2=SO_2 \quad \triangle F_{298}=-69757$

(15) The problem of the anorthosites. N. L. Bowen. J. Geol., 25, 209–243 (1917).

Anorthosites are made up almost exclusively of the single mineral plagioclase and in virtue of this fact they present a very special problem in petrogenesis. The conception of the mutual solution of minerals in the magma and the lowering of melting temperature consequent thereon is no longer applicable. Yet anorthosites give no evidence of being abnormal in the matter of the temperature to which they have been raised; in other words, they give no evidence of having been raised to the temperature requisite to melt plagioclase. A possible alternative is that they may never have been molten as such and are formed simply by the collection of crystals from a complex melt, probably gabbroic magma. This possibility is in harmony with the expectations that grow out of experimental studies and for this reason a consideration of the likelihood that anorthosites have originated in the stated manner becomes imperative.

A consideration of the method whereby accumulation of plagioclase crystals might take place leads to the conclusion that the most promising is the separation by gravity of the femic constituents from gabbroid magma while the plagioclase crystals, which are basic bytownite, remain practically suspended. Then, at a later stage, when the liquid has become distinctly lighter, having attained diorite-syenite composition, the plagioclase crystals, which are now labradorite, accumulate by sinking and give masses of anorthosite, at the same time leaving the liquid out of which they settle of a syenitic or granitic composition.

Some of the consequences of this manner of origin of anorthosite are as follows: Typical anorthosite very poor in bisilicates should not occur as small dikes, for a mass of accumulated crystals should have little invading power. A proportion of about 15 or 20 per cent bisilicates or other foreign material, such as orthoclase and quartz, should be necessary for the formation of small dikes. Typical anorthosite should for like reasons not occur as an effusive rock, a rather large proportion of minerals other than plagioclase being necessary before such an occurrence would become possible. Anorthosite should be intimately associated with gabbro, but perhaps as intimately with syenite or granite. Anorthosites should commonly be labradorite rocks rather than bytownite or anorthite rocks.

A consideration of anorthosites with special reference to the Adirondack and Morin areas gives some reason for believing that anorthosites do show the requisite characters. For the Adirondack area especially, evidence is adduced favoring the possibility that there anorthosite and syenite may still occupy the relative positions in which they were generated by the process outlined, the Adirondack complex being interpreted as a sheet-like mass with syenite above and anorthosite below.

Other monomineralic rocks present essentially the same problem and are restricted in their occurrence in substantially the same manner if we consider especially those that approach most closely to the strictly one-mineral character. All of the monomineralic rocks do occur, however, as dikes and dike-like masses in essentially contemporaneous, congeneric igneous rocks, a fact which may be interpreted as due to the intrusion of a heterogeneous, partly crystalline mass.

On the whole the inquiry gives considerable support to the belief that the monomineralic rocks, of which the anorthosites are perhaps the most important representatives, are generated by the process of collection of crystals under the action of gravity.

(16) The ferrous iron content and magnetic susceptibility of some artificial and natural oxides of iron. R. B. Sosman and J. C. Hostetter. Bull. Am. Inst. Mining Eng., 907–931 (1917).

The percentage of ferrous iron and the relative magnetic susceptibility in powder form have been determined on a number of artificial and natural oxides of iron. Artificial oxides made at 1100° and 1200° consist of a solid solution of Fe_3O_4 in Fe_2O_3. Their relative magnetic susceptibility is approximately proportional to their percentage of FeO, from Fe_2O_3 over to Fe_3O_4. The deviations may be partly accounted for by the effect of various factors, of which the fineness of grain of the powdered oxide is the most important, especially in the case of the more ferromagnetic members of the series. The colors of the powdered oxides depend both on their chemical composition and on their physical constitution, especially the fineness of grain.

In addition to the oxides whose susceptibility depends upon their content of FeO, there exists also a highly ferromagnetic form of Fe_2O_3, which appears to be rare in natural occurrence.

The natural iron-oxide minerals are similar to the artificial in being in many cases solid solutions of Fe_3O_4 in Fe_2O_3. Others are mixtures of Fe_3O_4 and Fe_2O_3. If the ferrous iron is not in solid solution or in magnetite admixture, the magnetic susceptibility falls below the normal.

Some natural oxides can be magnetically fractionated; in these cases the less magnetic portions are found to deviate more widely from normal than the more magnetic. The cause of this deviation is not yet entirely clear.

Martite is a pseudomorph after magnetite, but its constituent granules or fibers consist usually of a solid solution of Fe_3O_4 in Fe_2O_3. The ferrous iron content and the magnetic susceptibility of the specimens examined suggest that they have been produced at temperatures considerably higher than atmospheric.

(17) Zonal growth in hematite, and its bearing on the origin of certain iron ores. R. B. Sosman and J. C. Hostetter. Bull. Am. Inst. Mining Eng., 933–943 (1917).

The powdered oxide from certain crystals of hematite from Elba contains considerable FeO and can also be fractionated magnetically. It is therefore not homogeneous, as would be the case if the crystal were a uniform solid solution throughout. Analyses and magnetic measurements on a cross-section of an Elba crystal showed that the magnetic susceptibility and percentage of FeO vary, not irregularly, but continuously, being highest at the base and lowest at the free-growing tip of the crystal. The crystal is therefore zoned with respect to its FeO content.

Since Fe_3O_4 goes into solid solution in Fe_2O_3, forming a single solid phase of varying composition and properties, a zonal distribution of FeO is to be expected in an oxide of iron depositing from a vapor or solution. The occurrence of such zonal growth indicates continuously changing conditions of temperature, pressure, and concentration during the formation of the crystals. Several ore deposits of contact-metamorphic origin show a zonal distribution of ferrous iron, probably arising from the same causes as the zoning of the single crystals.

(18) The petrographic microscope, a useful tool in applied optics. F. E. Wright. J. Optical Soc. Amer., 1, 15–21 (1917).

In this paper the function of the petrographic microscope is outlined and its applicability to many problems in optics is indicated. It may be used to advantage in the determination of non-metallic materials, whether crystal-

lized or amorphous, in individual units or in aggregates, coarse or fine-grained, and of organic or inorganic nature. Refractive indices can be ascertained on grains a few microns thick, and other optical properties on grains 0.01 mm. or greater in diameter.

(19) The crystallization of menthol. F. E. Wright. J. Am. Chem. Soc., 39, 1515–1524 (1917).

The crystallization of menthol is interesting not only to the crystallographer but also to the physical chemist. Menthol appears in four different forms, α, β, γ, δ; three of these bear apparently monotropic relations to the stable α-form. Because of pronounced undercooling the melting temperatures of all four forms can be realized and their mutual relations can be studied directly under the microscope. On crystallization all forms of menthol show a pronounced tendency to the development of radial spherulites; these are roughly spherical in shape in the case of crystallization from the melt, but noticeably ellipsoidal on inversion of one crystal form into a second. The four forms of menthol are readily distinguished under the petrographic microscope. α-menthol shows dextrorotatory polarization, while the melt is levorotatory. In the formation of the different monotropic forms the initial temperature of crystallization appears to be the determinative factor.

(20) The thermodynamic reversibility of the equilibrium relations between a strained solid and its liquid. F. E. Wright and J. C. Hostetter. J. Wash. Acad. Sci., 7, 405–417 (1917).

Experimental proof is offered in this paper of the reversibility of the relations between a strained solid and its liquid. The mechanism of this action has been found to be exactly that postulated in 1862 by James Thomson from a purely theoretical basis, namely: that on crystallization each particle (atom or group of atoms) enters into the crystal state in the condition of the crystal at the point to which it becomes affixed; and that if the crystal be under a state of strain the freshly deposited particle enters into the same state of strain. This fact is essential if equilibrium relations are to exist between a strained crystal and its liquid, because only under these conditions can the relations be strictly reversible; and thermodynamic reversibility is necessary if the thermodynamic equations are to find valid application.

(21) Dispersion and other optical properties of carborundum. H. E. Merwin. J. Wash. Acad. Sci., 7, 445–447 (1917).

The dispersion of carborundum in the visible spectrum was determined for both ω and ϵ by means of prisms and a basal plate. Crystals which are black are fairly transparent in microscopic grains. Color has little effect on refractive index for red light. Following are some of the observed values: $\omega_{Li}=2.633$, $\epsilon_{Li}=2.673$; $\omega_{Na}=2.654$, $\epsilon_{Na}=2.697$; $\omega_{F}=2.700$, $\epsilon_{F}=2.749$; $\omega_{G'}=2.741$, $\epsilon_{G'}=2.794$.

(22) Optical properties and theory of color of pigments and paints. H. E. Merwin. Proc. Am. Soc. Testing Materials, 17, 494–526 (1917).

The hue, purity, and brightness of light diffused by a pigment or paint depend upon the refractive index, color absorption, size, shape, and texture of the pigment grains, and upon the refractive index, color, and continuity of the vehicle; and also upon the distribution of the grains in the vehicle.

A black pigment to be optically most effective should have (1) a refractive index equal to that of the surrounding medium, and (2) grains 1μ (or less) in diameter which should be (3) just barely opaque to all colors. All the ordi-

nary black pigments possess the third characteristic approximately, some of them the second, but only one of them—boneblack in its various forms—has the best refractive index.

A white pigment should have a high refractive index, should be even-grained with grains about 0.5 to 1.0μ in diameter. Finer grains diffuse blue light more than red light under certain conditions, *e. g.*, when mixed in oil with black or dark-red pigments. Thus blue-grays and purples result. Most white pigments contain enough very fine grains to give bluish grays. Control of size of grain is important. It is probable that the refractive index of certain zinc oxides made by the American process can be controlled advantageously.

Coloring efficiency must be considered as much from the standpoint of the hue and tone desired as of the absolute "quantity of color" obtained. Thus, although extremely fine division may favor the last factor mentioned when the pigment is used in a mixture with a strongly diffusing pigment, yet under other conditions size and shape of grain and refractive index are of great importance. For example, Harrison red in grains of one shape has about 10 per cent better diffusing power than in grains of another shape. The shifting of hue, especially of orange and yellow paints toward the green, due to admixed black, is considered in detail. The optical properties which determine whether a pigment will be best suited for producing tints or shades are discussed. Special methods of studying the optical properties of pigments have been used and a considerable number of optical constants determined. These properties can be applied in determinative work or to problems in chromatics.

(23) Adirondack intrusives. N. L. Bowen. J. Geol., 25, 509–512 (1917).

A reply to criticism by Professor Cushing of certain statements relative to Adirondack structure occurring in the paper "The problem of the anorthosites" (reviewed under No. 15 above).

(24) The determination of iron in glass sand. John B. Ferguson. J. Ind. Eng. Chem., 9, 941–943 (1917).

In the past, sand analyses generally have shown too low an iron content, and since the Geophysical Laboratory has taken up the problem of optical glass this has been the source of some rather vexatious delays. In fact, it has been necessary for us to reanalyze practically all the sands under consideration, and in this paper is proposed a new procedure, based on our recent experiences, to replace the older procedures which have been found to be inadequate. Before the correct iron content of a sand can be determined the sand must be completely decomposed. Simple treatment with hydrofluoric acid and sulphuric acid is not sufficient. Fusion of the residue with potassium pyrosulphate must be resorted to and even subsequent fusion with sodium carbonate in rare cases.

(25) The effect of strain on heterogeneous equilibrium. E. D. Williamson. Phys. Rev., N. S., 10, 275–283 (1917).

In previous discussions of this subject there has been a great deal of misunderstanding owing to the confounding of stress with what has been termed "unequal pressure," *i. e.*, a difference of the hydrostatic pressure on two phases in equilibrium. Since the effect of "unequal pressure" is of a different order of magnitude from the effect of a stress, this has resulted in some confusion. In the present paper equations are deduced for both cases and the underlying assumptions are discussed at some length.

(26) Aventurine labradorite from California. Olaf Andersen. Amer. Mineralogist, 2, 91 (1917).

In the course of the work on aventurine feldspars (Am. J. Sci. (4), 40, 351, 1915; reviewed in Year Book No. 14, p. 169), many specimens in the collection of the U. S. National Museum were studied. One of these, comprising a number of pebbles and six cut stones, from Modoc County, California, proved to be so different from the majority of the specimens that it was not described in the paper above cited. Being practically colorless and transparent, except for the inclusions which yield the red aventurine effect, the identity of the feldspar seemed worth establishing by optical and crystallographic measurements. The results are presented in this paper.

DEPARTMENT OF HISTORICAL RESEARCH.*

J. Franklin Jameson, Director.

The following report, the twelfth annual report rendered by the present Director, covers the period from November 1, 1916, to October 31, 1917. No changes have occurred in the staff of the Department during the year. From November to June, when he entered the service of the government, the Department had the aid of Dr. James A. Robertson. He had at that time completed his work upon the section of the Atlas of the Historical Geography of the United States confided to him, and deserves the expression of the Department's cordial thanks for his aid.

From the first of November until May, Dr. Frederick J. Turner, professor of American history in Harvard University, was present with the Department as Research Associate. His own researches during that period were concerned with the economic and social development of the Middle West, and were conducted partly at the offices of the Department, but mainly at the Library of Congress. Once a week, in lectures, he presented the results of these studies, and of long-continued previous researches in the same field, to the members of the staff. The pleasure and profit derived from these occasions were much enhanced by his private discussions, at other times, of various portions of the Department's work with the members of the staff who were engaged upon them, while the Director had the great advantage of daily association with Professor Turner and of discussions ranging over the whole field of the Department's work.

As in previous years, acknowledgment is cordially made of the favors constantly shown to the Department, with the greatest liberality, by the officials of the Library of Congress, and especially by Dr. Herbert Putnam, the Librarian, by Dr. Gaillard Hunt, chief of the Division of Manuscripts, and by Mr. P. Lee Phillips, chief of the Map Division. Grateful recognition is also made of special courtesies extended by the authorities of the library of Harvard University, especially during the summer months, to several members of the staff, and by those of the library of Bowdoin College.

WORK OF THE PAST YEAR.

REPORTS, AIDS, AND GUIDES.

In the last annual report the Institution was stated to be on the point of publishing the "Descriptive Catalogue of the Documents relating to the History of the United States in the Papeles procedentes de Cuba, deposited in the Archivo General de Indias at Seville," prepared for the Department by Mr. Roscoe R. Hill, now president of the

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Spanish-American Normal School at El Rito, New Mexico. The book was not in fact issued until February, but was sufficiently described in the last annual report. It has already fully proved its usefulness in the hands of investigators of Spanish Louisiana and Florida and of the Mississippi Valley in general. It is indeed capable, if its indications are properly followed up by investigators, of remaking large portions of that history, so slight hitherto has been the knowledge of the vast mass of information contained in the great collection to which the volume is a guide.

In the Director's last annual report mention was made, in connection with Dr. Hill's work, of the fuller guide to a portion of the same material, not intended for print, at least at present, but retained in manuscript in the offices of the Department, and constituting a calendar of about 143 legajos or bundles (out of 934, in the Papeles de Cuba, relating to the history of the United States), selected as the most important for that history. This calendar, embracing itemized descriptions of about 58,000 documents, was made in duplicate by Mr. Hill and his clerical assistants at Seville, on two sets of slips. Keeping one set in an arrangement by legajos, in the order in which the documents themselves are found, the Department has completed the process of arranging the other set in chronological order, so that henceforward it will be able to locate promptly in the archives, for the benefit of any historical inquirer, any important paper in the collection, in case the date is exactly or approximately known by the inquirer.

Mention was also made of ten sets of photographic prints, each embracing about 3,000 plates, covering the main series of regular official (civil) despatches, found in the Papeles de Cuba, and addressed by Spanish governors in Louisiana to the captain-general at Havana, and extending from the arrival of Ulloa as governor in 1766 to that of Carondelet at the beginning of 1792. These ten sets of photographs were made upon the calculation that that number of facsimile reproductions of these important documents, central to the history of Louisiana and of the Mississippi Valley during the period indicated, would be desired by libraries and other public institutions interested in the history of the United States. I am glad to report that within a few months of their being offered for sale all ten sets were taken, by the following nine institutions, and by one private purchaser: Harvard University Library, New York Public Library, Hispanic Society of America, Library of Congress, Howard Memorial Library, Newberry Library, University of Illinois Library, Missouri Historical Society, and Wisconsin State Historical Society. The sets were sold at the cost of photographic work and printing, no charge being made for the supervision in Seville and in Washington on behalf of the Carnegie Institution, nor for the elaborate calendar which accompanied each set as a table of contents. As the Department possesses the

negatives, it would be possible, though at greater expense, to furnish additional series of prints to other institutions which may desire them. It is also possible to furnish additional copies of the calendar to any institutions or persons to whom such a list would be of service.

The "Guide to the Materials for American History in the Archives of Russia," prepared for the Institution by Professor Frank A. Golder, of the Washington State College, was issued in February, as a volume of 177 pages. An outline of its contents, which have their chief value to the students of diplomatic relations between the United States and Russia and of the history of Russian America, was presented in the last report. In January, Mr. Golder again went to Russia, and has been there throughout the intervening months, including the period of the Russian revolution. While his present journey was not made at the instance or on the account of the Carnegie Institution, it is proper to mention in these pages the facilities granted him by the Russian government for the further prosecution of the task originally undertaken for the Institution. In respect to the archives of the Ministry of Foreign Affairs, containing the materials illustrating the diplomatic relations between Russia and the United States, Mr. Golder's permits extended to the year 1854. Before he started upon his present expedition the Russian government extended this privilege to the year 1870, and a further extension was granted after his arrival in Petrograd, so that he has been enabled to continue his studies through an interesting additional period of the international relations named; and these results, we may hope, it will be possible for the Institution, at some time, to place before those students who are interested in the field, as a supplement to the sections relating to it in the volume lately published.

From the first of November until early in May Mr. Leland continued his work upon his "Guide to Materials for American History in the Archives of Paris." He was still occupied with the editing of his notes on the manuscripts of the Bibliothèque National when, in May, he was appointed secretary of the National Board for Historical Service, an organization formed in order to coordinate, for the benefit of the Government and the public, the services which historical scholars can render to either in war-time. Since May Mr. Leland has given all of his time to its affairs.

In the last month of the year reported upon, October, Mrs. N. M. Miller Surrey, author of a book on the "Commerce of Louisiana, 1699-1763," and well acquainted, by personal researches, with those materials in the French archives which relate to the history of the Mississippi Valley, began the work of editing the body of notes upon such materials which during several years preceding the summer of 1914 had been taken by various assistants, under Mr. Leland's supervision, with a view to the composition of a calendar of all such papers.

This enterprise, the "Calendar of Papers in the Archives of Paris relating to the History of the Mississippi Valley," had its origin in the conference of historical societies which accompanied the meeting of the American Historical Association in 1907. A committee appointed on that occasion, and composed chiefly of members representing the historical societies and historical departments of States in the Middle West, resolved upon the preparation of such a calendar, intended to bring together, in a general list, notes of all the documents in those archives relating to that subject. This excellent cooperative undertaking was intended to prevent duplication of research in the French archives on behalf of the States of the Mississippi Valley and to make known to investigators every document in the archives of Paris relating to the history of that great region. Funds were subscribed by the various State historical societies and departments. The Carnegie Institution of Washington contributed the services of Mr. Leland as supervisor of the work. When the present war broke out the process of note-taking had been nearly completed, and more than 20,000 documents pertaining to the subject in view had been systematically described by his assistants. The funds originally raised have just sufficed for this process. This Department proposes to take up the work at the point now reached. A little additional work in Paris will complete the taking of notes. Mrs. Surrey has begun the editing of those already taken and the preparing of the manuscript for printing. The value of such a calendar will be at once apparent to all students of the history of the Mississippi Valley in the seventeenth and eighteenth centuries.

Work on the "Atlas of the Historical Geography of the United States" has been carried on chiefly in the Map Division of the Library of Congress, the facilities of which have been most obligingly placed at Dr. Paullin's disposal by Mr. P. Lee Phillips, chief of that division. Dr. Paullin has completed his series of maps illustrating the history of the international boundary controversies of the United States from 1776 to the present time, and the accompanying letter-press. He next turned his attention to the maps illustrating the history of boundary controversies between States. These maps, numerous and in some cases perplexing, have now been completed by Dr. Paullin, assisted by Mr. J. B. Bronson, of the Navy Department, as draftsman. Dr. Paullin has also completed the text of the letter-press illustrating this series. In the summer, he took up the series of maps intended to show at the beginning of each decade the extent and boundaries of each State, and to illustrate at the same time the growth of urban population by the indication of all towns of a certain size. In this series a considerable portion, of both maps and letter-press, has now been finished.

During the year Dr. James A. Robertson has finished his work upon that section of the Atlas devoted to reproductions of old maps, intended to exhibit the progress of geographical knowledge respecting America, the progressive opening up of the Continent by European and later by American explorers. The processes which he has carried through are those of examination and comparison of maps, determination of those which are most useful for the purpose in hand and most suitable for reproduction in such a book, arrangement of the maps on the series of plates, and composition of the letter-press. The maps selected will exhibit the development of knowledge of the Pacific as well as of the Atlantic and Gulf coasts, and likewise the progress of knowledge respecting the interior of the Continent. The letter-press will make plain the relation of one map to another, the significance of individual maps and the reason for their adoption into the series, and the history of the originals, of which photographic reproductions will be presented. In the selection, Dr. Robertson has had the benefit of advice from Dr. Edward L. Stevenson, secretary of the Hispanic Society of America, whose competence in all matters of early cartography is well known. Dr. Stevenson has also kindly permitted the use of two photographs from his own very remarkable reproductions of early maps, in cases in which a fresh photographing of the originals would now be attended with difficulties probably insuperable.

During the year reported upon Mr. Luis Marino Pérez, librarian of the House of Representatives of Cuba, and author of the Institution's "Guide to the Materials for American History in Cuban Archives," has completed and delivered the manuscript of his report upon the archives of the colony of Jamaica. The archives are shown to be important and valuable for American history, to a degree beyond what had heretofore been known, though damaged and disordered by earthquakes and other mishaps. This report is intended to be combined with similar surveys of the Lesser British Antilles, in a general volume on the West Indian archives.

In view of the fact that the island archives have suffered much from hurricanes and various other incidents of a tropical climate, many series in these archives are imperfect, and require to be completed by consultation of the corresponding series of transcripts which, under the colonial system of Great Britain, were required to be transmitted from the colonies to the central office of administration in London. Therefore anyone who wishes to present a general guide to the British West Indian materials for the history of the British Empire in America must combine in one view the appropriate portions of the archives of the individual islands. Accordingly it was thought, a year ago, that, though conditions attendant upon the existence of war made it inex-

pedient to attempt an archival expedition to the Lesser Antilles, a systematic examination of the West Indian portion of the Colonial Office Papers in the Public Record Office in London might be profitably undertaken, and it was hoped that this might be carried out, in some portion of the year just ended, by Professor Herbert C. Bell, of Bowdoin College, who had kindly consented to undertake the task whenever free to do so. Mr. Bell, however, has entered the military service of the United States, and the conditions are still so little favorable that no attempt will be made to have either the West Indian or the London portion of the enterprise carried out until the war has terminated.

TEXTUAL PUBLICATION OF DOCUMENTS.

The first volume of Dr. Davenport's collection of "European Treaties bearing on the History of the United States and its Dependencies," extending through the treaties of 1648, reported a year ago as completed in manuscript, is now all in type and approaching the date of publication. Page-proofs have been read, and proofs of the index, prepared by Mr. D. M. Matteson, of Cambridge, Massachusetts, are in the hands of the printer. Exclusive of the index, the book makes a volume of 366 pages. The documents which it presents, and which can be found in no other one collection of papal bulls and international treaties, are forty in number, ranging in date from 1454 to 1648 (treaty of Westphalia). Each treaty is preceded by an introduction, in which Miss Davenport describes the negotiations through which it was concluded, and brings out its significance in the history of the relations between Europe and the New World. Next follows a bibliographical statement as to text, translations, and works illustrative of the history of the treaty. Then follows the text, which in all practicable cases is based upon photographs of the original ratifications, and which has been prepared with the utmost pains as to minute accuracy. This, in the case of documents whose original language is not English or French, is followed by a translation. The introductions and texts are accompanied by learned annotations. The book, it is believed, will be useful to professional students of history and international law and to college and university classes.

During the past year Dr. Davenport has been engaged upon her second volume, and has completed her work upon eight of the treaties following that of Westphalia—treaties extending from the Anglo-Dutch Compact of Hartford, 1650, to the treaty of London between Great Britain and Sweden, 1656.

In Dr. Burnett's series of "Letters of Delegates to the Continental Congress," the first volume is entirely ready for printing at the time at which this report closes, and the second substantially so. The first

volume extends through July 4, 1776, the second to the end of 1778. Both will soon be offered for printing.

In order that the "Proceedings and Debates of Parliament respecting North America" might not prove too voluminous, as was at one time apprehended, an attempt was made to distinguish more severely the materials which should be regarded as belonging in the volumes from those which should be excluded. Besides votes and debates, it is intended that petitions, reports on petitions, and reports of committees shall be retained in full; but that accounts and estimates drawn from the Customs Office, War Office, etc., letters and papers of officers and individuals, and other like material which in its origin was not addressed to Parliament but which was called for incidentally in Parliamentary considerations, shall be excluded, except for mention by title. Measures have also been adopted for abbreviating certain parts of the Journal material. The finding of certain acts relating to the Newfoundland fisheries has pushed back the beginning of the volume from 1584 to 1542, and made necessary some further searching for Journal material, though it was supposed, a year ago, that the work on all journals had been finished. During the past year, up to the time when the National Board for Historical Service was organized, Mr. Stock devoted himself to the critical sifting of materials respecting debates and the gradual preparation and annotation of the final text of his first volume. This process had at that time been completed to the end of the reign of James I. From the beginning of summer to the end of October, Mr. Stock spent practically all of his time in work for the Board.

A further step toward the advancement of this series has consisted in the obtaining from London of copies of debate material in manuscripts of the British Museum, substantially complete to the end of the seventeenth century. A London photographer, engaged to reproduce the pages relating to America in Henry Cavendish's "Journal of Debates in the Parliament of 1768–1774," preserved among the Egerton Manuscripts in the British Museum, has completed this series of photographs. Most of the parcels of prints sent week by week have now arrived. It is believed that the photographs, even those of Cavendish's shorthand pages, which it will apparently not be difficult to decipher, will make substantial additions to our knowledge of proceedings relating to America in a Parliament otherwise but little reported.

Miss Donnan, in portions of her time not occupied with her work upon the *American Historical Review*, has continued her search for material upon the history of the African slave-trade, the sources and methods of supply, during the whole period between the beginning of the fifteenth and the beginning of the nineteenth centuries.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the *American Historical Review* has been carried on in the office of the Department and by its staff. Aid has been given in a number of ways to the American Historical Association, of which Mr. Leland is secretary, and to various other American historical societies and departments of history in the several States, for which investigations or other services could be performed in Washington. As in previous years, searches and copies have been made, in Washington archives, by the Department, or under its supervision, for a considerable number of inquirers. Some aid has been rendered to the group of scholars who have been bringing into existence the Hispanic-American Historical Review. But much the most important of such activities has been the rendering of all assistance the Department could render to the National Board for Historical Service.

PLANS FOR 1918.

All plans for the ensuing year are in greater or less degree contingent upon the development of historical work relating to the war. The National Board for Historical Service will no doubt continue in existence until the end of the conflict; but as the phases of the conflict change the historical work undertaken for the benefit of government or nation will to some extent change with them, developing in fresh directions to meet new needs, and sometimes leaving certain fields of work for exploitation by new agencies. Changes in the personnel of the Board, which may be expected to be caused by terms of academic duty, may also cause some alterations in the Board's program of activities. It will be the desire of the Department to aid the Board, in any of these activities, in whatever way it can, and therefore it is impossible to predict how largely the ordinary program of the Department may be affected by such diversion of its staff.

REPORTS, AIDS, AND GUIDES.

Mr. Leland will do what he can toward finishing that volume of his Guide to materials in Paris which concerns manuscripts in libraries. Conditions in Paris are now such that we may hope to complete the collecting of data for that volume within the next twelve months. The continuance of Mrs. Surrey's work on the Calendar of papers in the archives of Paris relating to the history of the Mississippi Valley, especially if it can be brought to a conclusion, will aid largely toward the finishing of Mr. Leland's work.

Dr. Paullin, with such appropriate assistance as can from time to time be invoked, will work upon the Atlas of the Historical Geography of the United States.

TEXTS.

The first volume of Miss Davenport's "European Treaties bearing on the History of the United States and its Dependencies" will no doubt be issued early in the year, while she proceeds with work upon the second volume, extending from 1648 to 1713.

Dr. Burnett will expend as large a part of his time as is possible in continuing the annotation of his "Letters of Delegates to the Continental Congress" and preparing the manuscript of the third and fourth volumes for publication.

Mr. Stock will endeavor to complete the first volume of his "Proceedings and Debates of Parliament respecting North America," extending from 1542 to either 1700 or 1715.

Miss Donnan will devote whatever time is not occupied with her duties in connection with the *American Historical Review* to further research in the history of the African slave-trade, relating especially to the sources and methods of supply.

MISCELLANEOUS OPERATIONS.

The Department will no doubt maintain, in 1918, activities similar to those which, under this heading, have been described above in that part of this report which relates to the year now closed.

DEPARTMENT OF MARINE BIOLOGY.*

ALFRED G. MAYER, DIRECTOR.

Early in the year the yacht of the Department was placed at the disposal of the United States Government. Permission was granted, however, to retain the vessel for use at Tortugas until August, when she was duly turned over to the Navy Department. We were thus enabled to spend a very successful season at Tortugas, despite the difficulty in maintaining research in pure science during this period of international conflict. Yet, if such research has been of value in the past, it must become even more necessary in the future, when we come face to face with the huge task of restoring civilization to the earth.

The Director, accompanied by Professor Lewis R. Cary, of Princeton University, and Mr. John Mills, our engineer, remained on the island of Tutuila, American Samoa, from March 4 to April 18, 1917, engaged in an intensive ecological, biological, and physiological study of the coral reefs surrounding this volcanic island.

In response to the request of the President of the Institution, the Secretary of the Navy gave us a letter of introduction to Captain John M. Poyer, U. S. Navy, governor of American Samoa, who together with his officers did all in their power to render our visit scientifically successful and socially delightful.

Professor Cary devoted his attention to the Alcyonaria, while Dr. Mayer studied the stony corals.

It was found that rain-water falling upon the island is acid, but when it reappears in streams or springs it has become neutral or slightly alkaline, due to bicarbonates or calcium, potassium, magnesium, and sodium, derived not only from the salt air surrounding the island, but chiefly through solution from the volcanic rocks. We see, then, that the stream-water pouring outward from this purely volcanic and densely forested island is not acid and can not therefore dissolve submarine limestones by reason of its "acidity." Thus the Murray-Agassiz theory to account for the origin of atolls and barrier reefs through submarine solution seems finally to be refuted, Vaughan and Dole having disproven it for the Tortugas and Bahama region.

It was proven that corals are not found off the mouths of streams simply because the silt and dilution prevent their growing in such places, and not because of solution of submarine limestones. Indeed, when a stream changes its course and flows out over the previously formed reef-flat it deposits sandbars, but does not dissolve the coral.

Squares were laid out over the reef-flat and all coral heads counted in order to determine the distribution of the various species over the

*Situated at Tortugas, Florida.

reef. Physiological studies showed that corals can usually adjust their metabolism to meet a wide range in the variation of the oxygen supply in the sea-water, and that the oxygen is always much more than sufficient for the corals, and death due to heat occurs at practically the same temperature for the same species of coral, whether the oxygen in the sea-water is normal, three times as great, or only one-third the normal. It seems, then, that Winterstein's hypothesis that death from heat is due to asphyxiation is not supported. Other studies made at Tortugas suggest that carbonic acid accumulates in tissues under the influence of high temperature more rapidly than it can be eliminated, and being toxic causes death.

Many Samoan corals were measured, weighed, and replaced on the reef, and it is hoped that we may return to Samoa in 1918 to drill through the coral reef, determine the growth-rate of Pacific corals, and evaluate the factors which may change fringing reefs into barriers, such factors being of value to navigation in the Pacific.

Professor L. R. Cary carried out ecological studies of Alcyonaria in Samoa, determined their temperature reactions, gathered data for estimating their growth-rate, and discovered their part in building up reef limestones. In order to complete these studies, it will be necessary for him to return to Samoa in 1918.

Upon our return, a day was spent upon Oahu, Hawaiian Islands, where Dr. C. Montague Cooke jr. kindly transported us to all the important streams and springs in the vicinity of Honolulu. We found these to be decidedly more alkaline than are the streams of Tutuila, due doubtless to the solution of the elevated limestones found upon Oahu, these being absent from Tutuila.

Daily tests were made of the surface-waters of the Pacific between San Francisco, California, and Pago Pago, Samoa. These showed that the surface-water under the equator is a fraction of a degree cooler than that in latitude 5° north or south of the equator, this being due to convection, the cold deep water coming to the surface. Also, the warm tropical water is more alkaline than is the cold current off the coast of California, and the easterly counter-currents met with occasionally upon the surface of the tropical Pacific are apparently apt to be less alkaline than is the water of the prevailing westerly drift. This suggests that these counter-currents may be in regions where deep-sea water is coming to the surface. In these studies use was made of a standardized set of thymolsulphonephthalein tubes made and presented by Professor J. F. McClendon. Later, at Tortugas, Professor McClendon found that the surface-waters of the ocean show a diurnal range in alkalinity, due to the photosynthesis of plant-cells. Thus he found that the water becomes relatively acid during the night, due to accumulation of CO_2, whereas in sunlight the plants consume the CO_2, thus augmenting the alkalinity of the water.

Hence the water of shallow impounded tide-pools or reef-flats becomes as alkaline as 8.6 P_H in sunlight, the normal ocean water being 8.2 P_H.

Only nine investigators studied under the auspices of the Department during the year, for war conditions and the uncertainty of our plans for the future rendered it undesirable to invite new men to commence studies at Tortugas; thus only those who had previously worked at Tortugas returned to extend or complete their researches. The following is a list of the investigators thus employed:

Name.	Place and time of study.	Subject.
Stanley C. Ball, Massachusetts Agricultural College.	Rebecca Shoal lighthouse and Tortugas, June 25 to July 30.	Migration of mosquitoes and other insects.
Paul Bartsch, U. S. National Museum.	Tortugas, July 15 to 30.....	Mutations of cerions transplanted from the Bahamas and West Indies to Florida Keys.
Lewis R. Cary, Princeton University.	Tutuila, Samoa, Mar. 4 to Apr. 18; Tortugas, June 25 to July 30.	Alcyonaria, ecology, and composition of coral reefs, temperature relations and oxygen consumption in Alcyonaria; metabolism and nervous reactions in *Cassiopea*.
Hubert Lyman Clark, Harvard University.	Tortugas, June 3 to 25......	Echinoderms.
Ulric Dahlgren, Princeton University.	....	Grant of $100 for study of electric organs in fishes.
E. Newton Harvey, Princeton University.	Japan.....................	Cause of phosphorescence.
Shinkishi Hatai.........	Tortugas, June 25 to July 30.	Starving in *Cassiopea;* brain weight of fishes; rats isolated on East Key, Tortugas.
W. H. Longley, Goucher College.	Tortugas, June 3 to July 30..	Submarine photography in the study of the relation between the coloration of fishes and their surroundings.
J. F. McClendon, University of Minnesota.	Tortugas, June 3 to July 30..	Sea-water as a physiological fluid; condition of calcium, oxygen content, alkalinity, and photosynthesis of plant-cells in sea-water; nerve-conduction and oxygen-consumption in *Cassiopea*.
Alfred G. Mayer, Carnegie Institution of Washington.	Tutuila, Samoa, Mar. 4 to Apr. 18; Tortugas, May 28 to July 30.	Metabolism, growth-rate, and physiology of corals; "shell shock" in invertebrates and fishes; temperature reactions; non-efficiency of stream-water as a solvent of submarine limestones.

In response to requests from President Woodward, Mr. G. R. Putnam, Commissioner of the U. S. Bureau of Lighthouses, granted a permit to Professor S. C. Ball to remain for one month at Rebecca Shoal Lighthouse in order that he might study the migrations of mosquitoes. Later, also, he granted permission to Professor W. H. Longley to land upon East Key in order to facilitate his study of the coloration of fishes.

Rebecca Shoal Lighthouse is out in the ocean, the nearest land being East Key, Tortugas, distant about 12 nautical miles; but the nearest region upon which any considerable number of mosquitoes can breed is Marquesas Atoll, 24 miles to the eastward. Professor Ball found that breezes from the north and east brought mosquitoes to the lighthouse, and on July 11 a swarm came with the strong southerly wind from Cuba, 95 miles away. This same swarm appeared also at Tortugas and became a pest for a few hours, causing us to retreat from the beach and retire at night under our mosquito bars, an unusual condition in this region, where mosquitoes are uncommon. Professor Ball's study makes it appear that strong winds can carry mosquitoes, flies, and other insects with the drift of air for 95 miles, and although it is not denied that mosquitoes may at times fly for considerable distances against light breezes, experience at Tortugas and Rebecca Shoal would seem to warrant the conclusion that a strong breeze is far more efficient in carrying them for long distances *with* the wind than is a light breeze in enabling them to fly *against* the wind.

Dr. Paul Bartsch visited the Tortugas, hoping to find many adult specimens of the second generation of *Cerion* snails born on the Tortugas, but these animals grow so slowly and he found so few adults that no conclusions can with safety be drawn. These cerions were brought in 1912 and at other times from Andros Island, Porto Rico, Curaçao, and the Bahamas to Tortugas and other Florida keys and have flourished remarkably well in some places, the first generation being generally larger than their Bahama and West Indian ancestors.

Professor Lewis R. Cary is extending to the Pacific his determination of the share alcyonarian corals take in building up reef limestones, and also studying the reaction to temperature, growth-rate, ecology, and metabolism of these forms and has demonstrated that they contribute more limestone to the Florida-Bahama reefs than do the madreporarian corals. It will be necessary for him to return to Samoa in order to ascertain the growth-rate of these forms and to drill through the reef and obtain a core to determine the relative amounts of madreporarian and alcyonarian materials constituting the limestone. Other researches undertaken by Professor Cary are referred to in his report published herewith.

Dr. Hubert Lyman Clark collected echinoderms at Tortugas and found 75 species on the reefs and in the channels of the group. The region thus appears to be as rich in number of species as is any other part of the West Indies, although some forms which are abundant elsewhere are rare at Tortugas.

Dr. Shinkishi Hatai found that the brain-weight in the gray snapper, *Neomœnis griseus*, a common predatory fish of the Florida reefs, bears a linear ratio to the body-weight. He also carried out a study of the changes occurring in *Cassiopea* during starvation and found that the

relative water-content remained unchanged during starvation, while the nitrogen varies.

A study of albino rats liberated by Professor Henry H. Donaldson in July 1916, on East Key, Tortugas, showed that the animals had bred upon the key and were feeding upon *Ocypoda* crabs and grass seed. The weight of the brain and of the spinal cord has become relatively heavier in these rats now living under the trying conditions imposed by the small semi-desert islet East Key, which lacks a supply of fresh water and provides only a limited range of food for the rats.

Professor William H. Longley made much use of a submarine camera, with which he photographed the reef fishes in their natural environment, demonstrating that the colors of these fishes blend with their surroundings to a remarkable degree. These pictures often show every scale and are in the best of focus, and yet the general shade of color of the fish so closely matches that of its surroundings that it is exceedingly difficult to discover the fish. Professor Longley has thus demonstrated that the reef fishes of the West Indies are remarkable for the many different ways in which they attain inconspicuousness. Crabs also illustrate the same law.

Professor J. F. McClendon carried out an extensive and interesting series of observations upon the physiological properties and calcium content of sea-water at Tortugas. Some of his conclusions have already been referred to in this report and others will be found in the Proceedings of the National Academy of Sciences and in his report published herewith. He was enabled to discover some very interesting facts, such as the diurnal change in CO_2 content of the surface waters of the ocean, the conditions under which calcium is precipitated in the tropical ocean, and the respiratory quotient of animals which have symbiotic plant-cells and can thus maintain their own oxygen supply in sunlight, even oxygenating the surrounding sea-water. He also found that when nerves of *Cassiopea* are stretched the rate of nerve-conduction remains the same, and thus it takes a longer time to go through a stretched nerve in proportion to the lengthening of the tissue.

As a result of studies made at Tortugas, Alfred G. Mayer concludes that death of certain corals from high temperature may be due to the accumulation of acid in the tissues. He also attempted to determine the efficacy of holothurians as destroyers of sand over reef-flats, and he determined the law of the rate of nerve-conduction in concentrated sea-water of the same degree of alkalinity as normal sea-water. Experiments in "shell shock" in invertebrates yielded negative results. Accounts of these researches appear in the special reports published herewith.

Volume XI of Papers from the Department of Marine Biology, published by the Carnegie Institution of Washington, appeared in July and contains 360 pages, 21 plates, 69 text-figures, and 14 papers.

Delays incident to the war have held back each of the two volumes upon the expedition to Australia in 1913, but it is hoped that at least one volume will soon appear, as will also Volume XII of Papers from the Department of Marine Biology.

The following papers, based upon studies made at Tortugas, are known to have been published during the year, or not previously reported, by agencies other than the Carnegie Institution of Washington:

CARY, LEWIS R., 1916. The influence of the marginal sense-organs on metabolic activity in *Cassiopea xamachana* Bigelow Proc. Nat. Acad. Sci., vol. 2, No. 12, pp. 709–712.

———, 1917. The influence of the marginal sense-organs on functional activity in *Cassiopea xamachana*. Anat. Rec., vol. 11, No. 6, pp. 527–530.

———, 1917. The part played by the *Alcyonaria* in the formation of some Pacific coral reefs. Proc. Nat. Acad. Sci., vol. 3.

DAHLGREN, ULRIC, 1917. Production of light by the lower insects. Jour. Franklin Institute, pp. 79–95, 9 figs., January.

———, 1917. Production of light by the elaterid beetles. Jour. Franklin Institute, pp. 211–222, 7 figs., February.

———, 1917. Production of light by the lampyrid beetles. Jour. Franklin Institute, pp. 323–349, 23 figs., March.

———, 1917. Production of light by the Cephalochordata. Jour. Franklin Institute, pp. 422–451, 10 figs., April.

———, 1917. Production of light by the tunicates and elasmobranch fishes. Jour. Franklin Institute, pp. 735–755, 10 figs., June.

GOLDFARB, A. J., 1917. Variability of germ-cells of sea-urchins. Proc. Nat. Acad. Sci., vol. 3, pp. 241–245, April.

HARVEY, E. BROWNE, 1917. A physiological study of *Noctiluca*, with special reference to light production, anæsthesia, and specific gravity. Proc. Nat. Acad. Sci., vol. 3, pp. 15–16, January.

HATAI, S., 1917. On the composition of the medusa *Cassiopea xamachana* and the changes in it after starvation. Proc. Nat. Acad. Sci., vol. 3, pp. 22–24, January.

JORDAN, H. E., 1917. Aortic cell-clusters in vertebrate embryos. Proc. Nat. Acad. Sci., vol. 3, pp. 149–156, March.

———, 1917. The history of the primordial germ-cells in the loggerhead turtle. Proc. Nat. Acad. Sci., vol. 3, pp. 271–277, April.

LONGLEY, W. H., 1916. Observations upon tropical fishes and inferences from their adaptive coloration. Proc. Nat. Acad. Sci., vol. 2, pp. 733–737, December.

———, 1917. The selection problem. Amer. Nat., vol. 51, pp 250–256, April.

———, 1917. Studies upon the biological significance of animal coloration: I. The colors and color changes of West Indian reef-fishes. Jour. Exp. Zool., vol. 23, pp. 536–601, August.

———, 1917. Studies upon the biological significance of animal coloration: II. A revised working hypothesis of mimicry. Amer. Nat., vol. 51. pp. 257–285, May.

MAYER, A. G., 1917. Coral reefs of Tutuila. with reference to the Murray-Agassiz solution theory. Proc. Nat. Acad Sci., vol. 3, pp. 523–526, August.

———, 1917. Further studies of nerve-conduction in *Cassiopea*. Amer. Jour. Phys., vol. 42, pp. 469–475.

———. On the non-existence of nervous shell-shock in fishes and marine invertebrates. Proc. Nat. Acad. Sci., vol. 3, pp. 597–598.

MCCLENDON, J. F., 1916. The composition, especially the hydrogen-ion concentration, of sea-water in relation to marine organisms. Jour. Biol. Chem., vol. 28, pp. 135–152, December.

PRATT, H. S., 1914. Trematodes of the loggerhead turtle (*Caretta caretta*) of the Gulf of Mexico. Archives de Parisitologie, tome 16, pp. 411–427, pls. 4 and 5, 13 figs.

In conclusion, it is a great pleasure to express our appreciation of the fidelity and enthusiastic interest in their work exhibited by the crew of the *Anton Dohrn*, and especially of Mr. John W. Mills, chief engineer, to whose activity, interest, and intelligence we owe much of the success of our trip to Samoa.

REPORTS OF INVESTIGATORS.

Report on Insect Investigation, by S. C. Ball, Massachusetts Agricultural College, Amherst, Massachusetts.

In order to determine whether mosquitoes migrate from the mainland and from Cuba across the sea to the Tortugas and neighboring points on the Florida reef, I spent the period from June 26 to July 18 upon the Rebecca Shoal light-station. Observations were carried out there to avoid the uncertainty arising at Tortugas on account of the breeding of mosquitoes upon the islands.

The light-house is isolated in 12 feet of water, 12 nautical miles east of the easternmost of the Tortugas keys, the nearest land; 24 miles of open sea separate Rebecca Shoal from the Marquesas Atoll on the east. The nearest point on the mainland of Florida is Cape Sable, 105 miles to the northeast. Tampa Bay lies very nearly due north at a distance of approximately 185 miles. The nearest point on the Cuban coast is Havana, 95 miles south, while the distance from Rebecca Shoal to Cape San Antonio, at the western extremity of Cuba, is about 230 miles.

The breeding conditions at the lighthouse were easily controlled. The fresh-water reservoirs were examined daily, no larvæ or eggs being found in them at any time. Two other sorts of receptacles which at times contained water were the small boats suspended from the davits and several depressions in the iron work of the substructure. The water in the boats, besides being easily examined, was covered with a film of lubricating oil from the gasoline engines, while extremely rapid evaporation prevented any eggs deposited in the small pockets of the iron-work from producing a brood of mosquitoes.

Since none bred at Rebecca Shoal during the period of observations, those which appeared could be accounted for only by their having been carried there by vessels, by birds, or on their own wings, with or without the aid of wind, or else by their having been on the structure at the time of my arrival. Now, the station is small, 24 feet square by 26 feet high, and kept scrupulously clean and free from litter. Hence it was easy to make a thorough search at the beginning. Not a mosquito at any stage of its existence was heard or seen for several days, good evidence that none were present. No vessels of any description passed within 2 miles of the lighthouse, except two small launches, which were carefully examined. That birds could be responsible for the introduction of other than parasitic insects is, of course, absurd.

We are therefore to conclude that any mosquitoes encountered must have flown or have been carried across the sea. Indeed, it will appear from the table of weather conditions and the arrival of mosquitoes that this is the only logical conclusion; only during and immediately following winds blowing steadily for several hours from the direction of the nearer land areas—Florida, Cuba, and Marquesas—were mosquitoes and other flies taken.

It may be stated that, with the exception of a single mosquito which escaped in an attempt to make its capture during a high wind, all mosquitoes and house-flies seen were captured and preserved.

Mosquitoes found in 23 days at Rebecca Shoal lighthouse.

Date.	Wind.	No.	Date.	Wind.	No.
June 26–30	E., light	0	July 9	E. to NE., light	6
July 1	Do.	1	July 10.	E., 5 a. m.	0
July 2	ENE., light	0		Calm, 4 p. m.	
July 3	N. at 5 a. m.			SE., 8^h30^m p. m.	
	NE. at 10 a. m.	0	July 11.	WSW., fresh, 5 a. m.	
	N. at 12 noon			SW., light, 5 p. m.	37
	N., freshening in p. m.			SW., calm, 9 p. m.	
July 4	N., light in a. m.	4	July 12.	ESE., fresh to strong	7*
	N. by W., fresh in p. m.		July 13.	E. by S., strong	1
July 5	N., light in a. m.	21	July 14.	Do.	0
	ENE. to E. by N., mod. in		July 15.	Do.	0
	p. m.		July 16.	Do.	0
July 6	ESE. to NE., fresh in p. m.	2	July 17.	Do.	0
July 7	E., light	0	July 18.	Do.	0
July 8	Do.	4			
				Total	83

*In forenoon.

On July 1, during a period of east winds, a single mosquito was caught. Not until the morning of July 4, after the wind had been blowing lightly but steadily from the north for 27 hours, did another appear at the station; 1 was taken at 8 a. m. and 3 more between 6 and 7^h30^m p. m.

July 5 proved to be one of the days on which mosquitoes were sufficiently numerous to be distinctly in evidence by virtue of their humming and biting. The first specimen was taken at 4^h30^m a. m. Between 5^h30^m and 8^h15^m a. m. 13 more were captured. During the rest of the day individuals taken at 8^h36^m, 9^h20^m, 11^h45^m a. m. and 12^h02^m, 4^h30^m, 7, and 8^h06^m p. m. brought the total to 21 mosquitoes. The moderate wind which had blown steadily from the north throughout the night of July 4–5 continued so until 5 p. m., when it veered into the east and freshened. It is important to note that, following this change, only 2 mosquitoes were taken on July 6, both of these early in the day.

Judging from this sudden and marked increase in the number of mosquitoes visiting the lighthouse following a change of 90° or more in the direction of the wind, as well as the fact that a period of at least 27 hours elapsed between the time that this change began and the arrival of the first mosquitoes at Rebecca Shoal (5 a. m. July 3 to 8 a. m. July 4), it seems a fair conclusion that they must have been carried from some point on the west coast of Florida. Furthermore, all of the 25 specimens were salt-marsh mosquitoes; that is, the larvæ have been found only in the strongly brackish waters of coastal marshes. Of those taken on July 4 a single one belonged to the species *Ochlerotatus sollicitans* Walker, while the other 3 and the 21 taken on July 5 were *O. tæniorhynchus* Wiedemann. As Dr. J. B. Smith and his assistants so clearly demonstrated in New Jersey during their investigations of 1902–04, *O. sollicitans* has the remarkable habit of migrating inland in immense swarms for distances of 30 miles or more in search of food. Of the second species as observed in his State, Dr. Smith says: "*Culex tæniorhynchus* develops with *cantator* and *sollicitans* under the same conditions and migrates with them; but it does not fly so far and is always so much less abundant that it requires no special account here." It therefore appears that the southern representatives of these two species have similar migratory habits. But instead of being found 15 miles out at sea, as Dr. Smith mentions their having been seen in the north, our observations indicate that large numbers of them are carried

by the wind a minimum distance of 105 nautical miles from the region of Cape Sable. Some of them may have traveled the 180 miles from Tampa Bay; the direction of the wind would have made this possible.

On July 6, when the wind had been blowing for 12 hours from the east, only 2 mosquitoes were taken, both being *O. tæniorhynchus*. These, as well as the 4 captured on July 8 and the 6 on July 9, no doubt came from some key—probably Marquesas—to the eastward of the Florida reef. They are known to breed there.

The second remarkable migration of mosquitoes occurred at Rebecca Shoal on July 11, following a change of the wind on the 10th from east through southeast to southwest. The first specimen was taken at 5^h30^m a. m., 2 more at 7^h30^m, another at 8^h15^m, and during the ensuing period until 1^h35^m p. m., 19 mosquitoes, one at a time. Between 3^h30^m and 5^h09^m p. m., 3 more were added, followed by the last 7 captured between 6^h30^m and 7 p. m. It is important to record that the cessation of mosquito arrivals coincided with the dying out of the wind at dusk. 34 specimens of *O. tæniorhynchus* and 3 of *O. sollicitans* had been taken during the day on an actual area of the ocean's surface only 40 feet square. It should be borne in mind, however, that the sense of smell possessed by the mosquitoes undoubtedly increased the area within which those taken may be regarded as having been distributed.

The source of the mosquitoes reaching Rebecca Shoal on this south and southwest wind must have been some portion of the Cuban coast. As stated above, the shortest distance in this direction is 95 miles from Havana and the longest 230 miles from Cape San Antonio on the southwest.

My experiences at Rebecca Shoal on July 11 were supplemented by those of Dr. A. G. Mayer and other observers at Loggerhead Key, 18 miles to the westward. Under the same wind conditions Dr. Mayer notes that "mosquitoes were noticed at about noon of July 11, and became a pest by night, so that we were unable to lie on the sand at the northern end of the island. Many of them were also found in the laboratory, and they were thick in the bushes near the buildings and on the ocean about 300 feet from the shore on the west side of the island. During the night of July 11–12 the wind veered to southeast by east-southeast and the mosquitoes practically disappeared." All of the 22 specimens taken by Dr. Mayer on the above date proved to be *O. tæniorhynchus*.

The last hours of the southerly winds brought 7 more of the same species to Rebecca Shoal on the forenoon of July 12. On the night of July 12–13 the wind veered into the east, blowing steadily and strongly from east by south for the remaining 6 days of my stay there. That no more mosquitoes were taken may be accounted for by the fact that any leaving Marquesas must have been carried a few points to the northward. It is unlikely, moreover, owing to the force of the wind, that insects could have alighted, except in the lee of the station.

Of paramount interest are the observations made at Rebecca Shoal concerning the forced migration of the common house-fly, *Musca domestica*. During the light east winds from 3 to 5 specimens were taken per day. Therefore the capture of 25 on July 6, following a quick change of the wind from north to east was very striking. The inference is that they were brought from points eastward on the reef or possibly from the southern extremity of Florida. On July 7 the numbers of *Musca domestica* visiting the station dropped to 5, the normal for light east winds; 5 more were taken on the 8th and 3 on the 9th. It is interesting to note that none appeared on the 10th while the wind was changing to south. Along with the 37 mosquitoes, 18 house-flies arrived from Cuba on July 11. Although the wind on the 12th was south-southeast, 7 were taken

in the forenoon, possibly arrivals of the previous night. During the succeeding days of high east by south winds very few appeared, 1 on July 13, 2 on the 14th, 1 on the 15th, and 1 on the 17th.

A large moth, evidently from Cuba, was seen to come up to the lighthouse at 10 a. m., July 12, and alight on the boat rigging. Its capture proved it to be the strong-flying species *Syntomeida epilais* Walker.

Other insects which visited the station were a green blow-fly (*Lucilia*) on June 27 (wind east); a *Tabanus* on June 29 (wind east); a small gnat on July 2 (wind east-northeast); a dragon-fly seen but not caught on July 5; a *Tabanus* on July 7 (wind east); 3 blow-flies (*Lucilia*), 1 small fruit-fly, and a *Chrysopa* on July 8 (wind east); 1 *Lucilia* on July 10 (wind very light east).

Three of five female *Ochlerotatus tæniorhynchus* deposited batches of eggs in a dish of fresh water 3 days after being inclosed in a cage on July 12. The insects were allowed to bite before confinement.

During the period from July 18 to 30, which I spent at Tortugas, I found *O. tæniorhynchus* fairly abundant on Loggerhead and East Keys. There is certainly no breeding-place for mosquitoes on the latter, while none was discovered as eggs or larvæ on the former. All but one of the cisterns of fresh water at Fort Jefferson on Garden Key had some weeks earlier been treated with kerosene. The untreated reservoir contained a considerable number of larvæ and pupæ of *Culex pipiens*. Several were reared to maturity and the adults preserved, the males emerging before the females, as might be expected. Since many specimens of *Stegomyia calopus* were captured on Loggerhead and East Keys, it is possible that they were reared in this cistern, although no larvæ were discovered.

On Loggerhead Key an attempt was made to determine whether or not *Musca domestica* would breed in dead crabs. The results were negative; the females would deposit no eggs. It was found, however, that the beach-flies, *Sarothromyia femoralis* Schiner and *Sarcophagula occidua* Walker, breed readily in such matter. One crab (*Ocypoda arenaria*), whose carapace measured 1.5 inches in breadth, yielded 104 pupæ, the living maggots being deposited by 11 flies on July 19 and the pupæ removed from the bottom of 3 inches of sand on July 29. Three imagoes had already emerged at that time and were clinging to the bolting-cloth cover of the glass breeding-jar.

In conclusion, it is a pleasure to give expression to my gratitude to Hon. G. R. Putnam, U. S. Commissioner of Lighthouses, for permission to reside in Rebecca Shoal Lighthouse, and especially to Mr. Lopez, the head keeper, and his assistants, with whom I spent a very pleasant month.

Report on the Bahama Cerions planted on the Florida Keys, by Paul Bartsch.

It was hoped that a large number of adult specimens of the second generation of cerions would be present this year, but only 9 mature individuals of this generation were obtained of Colony C, "White House type," and 2 of Colony K, "King's Road type," on Loggerhead Key, Tortugas; yet these specimens, though few in number, show that profound changes have taken place in this generation.

The shells at hand from both colonies are much smaller than those of the first generation, and, what is more remarkable, even smaller than those of the original planting. It is to be hoped that the coming year may yield a larger number of this generation, or, at all events, enough for a thorough tabulation.

It seems quite well established now that about 3 years are required to obtain a full crop of a new generation, and it is to be hoped that we may yet be able to make a new planting on a large scale, which will give us a much larger series of offspring than we have so far obtained from our limited colonies.

Fifth Annual List of Birds observed on the Florida Keys, by Paul Bartsch.

Various conditions prevented me from joining the Director in the usual cruise among the Florida Keys in April, and my visit had to be delayed to the last part of the laboratory season. The notes on birds which I have to offer this year were made between July 14 and August 1, and are of interest chiefly on account of the small number of species recorded from all the stations this season. The complete absence of passerine forms at the Tortugas at this time can probably be accounted for by the lack of available fresh-water on these keys. In spite of the small number of forms noted, 35 in all, 3 belonged to species not listed before; namely, the common tern (*Sterna hirundo*), the black tern (*Hydrochelidon nigra surinamensis*), and the semipalmated plover (*Aegialitis semipalmata*).

It was interesting to find the rather large colony of common terns established on Bush Key this year. The black terns observed on the same key are somewhat puzzling, as I scarcely believe that they bred there, and yet if they were autumn migrants why should their presence be confined to this key?

At dawn on July 14 I took a position on the rear platform of the Oversea Railway and noted the birds as they came to view. The morning was cloudy, with occasional showers, and this may have been partly responsible for the lack of activity displayed among the smaller forms, for our list this year shows a decidedly less number than that obtained in previous years. It is true that the breeding-season was long over for the smaller species, and the molting period following usually sends them into seclusion. I will note the keys in their order from north to south, with the birds seen on each.

Jewfish Key: Turkey buzzard.
Key Largo: Turkey buzzard, Bahama red-winged blackbird, Louisiana heron.
Plantation Key: Turkey buzzard, 2 Florida ground doves.
Quarry Key: Florida ground dove, Bahama red-winged blackbird.
Upper Matecumbe Key: Bahama red-winged blackbird, Florida red-bellied woodpecker.
Lower Matecumbe Key: Willet, turkey buzzard.
Long Key: Least tern (small flock), Ward's heron, Bahama red-winged blackbird, turkey buzzard, Florida ground dove.
Grassy Key: Osprey (3 individuals), boat-tailed grackle.
Fat Deer Key: Boat-tailed grackle, osprey, man-of-war bird.
Key Vaca: Osprey, Florida crow, boat-tailed grackle.
Spanish Harbor: Green heron, osprey, willet, Louisiana heron, Florida ground dove, boat-tailed grackle.
Big Pine Key: Bahama red-winged blackbird, boat-tailed grackle (small flock).
Ramrod Key: Florida red-bellied woodpecker.
Summerland Key: Louisiana heron (small flock).
Cudjoe Key: Louisiana heron (small flock), willet, turkey buzzard.
Chase's Key: Louisiana heron, green heron.
Big Coppit Key: Great white heron (2), Bahama red-winged blackbird (7), Louisiana heron (small flock), Ward's heron, ruddy turnstone (8).
Boca Chica Key: Bahama red-winged blackbird, osprey, boat-tailed grackle, turkey buzzard, Louisiana heron.
Key West: Boat-tailed grackle, man-of-war bird.

July 15.—In a trip through the upper end of Key West, the following birds were noted: man-of-war bird, laughing gull (immature), turkey buzzard, boat-tailed grackle, gray kingbird, Florida ground dove, Ward's heron, Louisiana heron, Bahama red-winged blackbird, mourning dove, great white heron, least tern.

On the same day Stock Island was visited, and there the following birds were noted: Ward's heron, least tern, gray kingbird, turkey buzzard, black-billed cuckoo, Key West vireo, Florida ground dove, boat-tailed grackle, Florida red-bellied woodpecker, Florida crow, Florida cardinal.

July 17.—The following birds were seen about the city of Key West to-day: man-of-war bird, laughing gull, great white heron, boat-tailed grackle, Florida ground dove, gray kingbird, brown pelican, turkey buzzard.

July 18.—Between Key West and Boca Grande, the following birds were noted: man-of-war bird, laughing gull, royal tern.

On Boca Grande Key we saw great white heron, green heron, Florida clapper rail, gray kingbird.

Between Boca Grande and Rebecca Light, a couple of royal terns only were observed.

Off East Key, Tortugas, we noted least terns, sooty terns, and noddy terns.

At the Tortugas all the birds observed belong to the sea or beach-roving type.

On Loggerhead Key, sooty and noddy terns could be seen flying about at all times of the day. A bunch of least terns, varying from 10 to 25, frequented the hook of the northern sandspit daily, where they were often joined by royal terns, of which as many as 14 were seen at one time in their company. There is an interesting feature connected with the least-tern group at this point, for here they were constantly subjected to annoyance by the ghost crabs (*Ocypoda albicans* Bosc). Large members of this species would sidle up to the resting birds and, in spite of the vigorous wing beating to which they would be subjected by the tern, would force the latter from the place it was occupying. I am at a loss to account for this persistent persecution. If the least tern had been breeding at this place, one might be led to believe that the crabs were after the young fledglings, but since the terns were not breeding here, this does not seem possible. It likewise seems unreasonable to believe that these ghost crabs had acquired this habit in another place where the terns might be breeding and had later migrated to this sandspit, for ghost crabs usually stick pretty close to their burrows. I do not believe that the crab is capable of overcoming an adult bird.

On this sandspit, also, we saw, on several occasions, a flock of 7 least sandpipers. Man-of-war birds also occasionally passed over the island. At the southern end of the island a few least terns made their home. It is quite possible that they may have bred here, although I was unable to find evidences of young birds. It will be remembered that a single nest with eggs was discovered here last year.

On the 23d a green heron was seen at the southern end, and the following day a Ward's heron, which concludes the Loggerhead list.

Bird Key contained its usual host of breeding noddy and sooty terns and a large assemblage of man-of-war birds, which frequented the stakes and stumps and wreckage on this key. The stakes between Bird Key and Garden Key were occupied by a couple of red-footed boobies, as in the past year, the royal terns being fewer in number than in the earlier part of the season.

Garden Key, on the various visits made to it, revealed an osprey, and least terns, sooties, and noddies, the last three always on wing.

Bush Key has been united with Long Key since the hurricane of October 1910. The latter stretches eastward to the outer edge of the reef, and this complex forms a habitat possessing all the requirements to render shore birds happy. We found this by far the most interesting land element of the entire Tortugas group, excepting, of course, Bird Key, this year, for here a colony of probably 200 common terns formed a rookery on the rough coral shore of the eastern end of the island. Their young birds of various ages could be seen at all times. The least terns, too, were breeding all over the sandy beaches on the part which formerly constituted Bush Key, and here we found a few eggs and young of various stages. One young bird was discovered with one wing

nipped off at the primaries, an injury probably inflicted by a ghost crab. A few royal terns were also present at various times, and a pair of adult, noisy laughing gulls always objected to our intrusions. Sooty and noddy terns and man-of-war birds could be seen flying overhead most of the time, but the most interesting tern element on this key was a couple of dozen black terns ranging in plumage from the fully adult blacks through the checkered to the immature of the year, the latter forming the greatest number. These birds were seen on my first visit to this key on July 19, and were present at the end of the month. Their occurrence at the first date seems almost to indicate that they might have bred here, though I greatly doubt if that could have been the case, for we have no record of a colony as far south as this. A small flock of 4 brown pelicans was also present. An osprey divided his time between Bush Key and the fort on Garden Key, and a Ward's heron usually was noted keeping vigil on the inside of the outer reef. Five species of waders were seen on all the dates on which the Key was visited. These were a flock of some 20 ruddy turnstones, a single sanderling, small scattered flocks of least sandpipers, several semipalmated plovers, and 6 black-bellied plovers.

The small Sand Key, Tortugas, occasionally harbors a few royal terns and least terns.

On July 31 we stopped at Marquesas Island, where we noted the following birds: royal tern, brown pelican (6), great white heron (3), Ward's heron, American egret, Louisiana heron, green heron, yellow-crowned night heron, osprey, and gray kingbird.

Scientific Equivalents for Common Names of Birds Used in Preceding List.

Laughing gull = Larus atricilla.
Royal tern = Sterna maxima.
Common tern = Sterna hirundo.
Least tern = Sterna antillarum.
Sooty tern = Sterna fuscata.
Black tern = Hydrochelidon nigra surinamensis.
Noddy tern = Anoüs stolidus.
Red-footed booby = Sula piscator.
Brown pelican = Pelecanus occidentalis.
Man-of-war bird = Fregata magnificens.
Great white heron = Ardea occidentalis.
Ward's heron = Ardea herodias wardi.
American egret = Herodias egretta.
Louisiana heron = Hydranassa tricolor ruficollis.
Green heron = Butorides virescens virescens.
Yellow-crowned night heron = Nyctanassa violacea.
Florida clapper rail = Rallus crepitans scotti.
Least sandpiper = Pisobia minutilla.
Sanderling = Calidris alba.
Willet = Catoptrophorus semipalmatus semipalmatus.
Black-bellied plover = Squatarola squatarola cynosuræ.
Semipalmated plover = Aegialitis semipalmata.
Ruddy turnstone = Arenaria interpres morinella.
Mourning dove = Zenaidura macroura carolinensis.
Ground dove = Chæmepelia passerina passerina.
Turkey buzzard = Cathartes aura septentrionalis.
Osprey = Pandion haliætus carolinensis.
Black-billed cuckoo = Coccyzus erythropthalmus.
Red-bellied woodpecker = Centurus carolinus.
Gray kingbird = Tyrannus dominicensis.
Florida crow = Corvus brachyrhynchos pascuus.
Bahama red-winged blackbird = Agelaius phœniceus bryanti.
Boat-tailed grackle = Megaquiscalus major major.
Florida cardinal = Cardinalis cardinalis floridanus.
Key West vireo = Vireo griseus maynardi.

Alcyonaria as a Contributing Factor in the Formation of Some Pacific Coral Reefs, by Lewis R. Cary.

During the period from March 2 to April 18 the writer had the privilege of studying the Alcyonaria on the reefs of the island of Tutuila, American Samoa. While the reefs of the Samoan Islands are by no means among the

richest of the south Pacific reefs, they represent a condition from which general conclusions may be more safely drawn than from those prevailing upon the much richer reefs farther to the westward.

On account of the limited time at our disposal, practically all of our observations were confined to the reefs in Pago Pago Harbor. In this harbor, which occupies an old crater bottom open on one side, one finds a series of environmental conditions embracing all those occurring on any of the reefs about the island. The reefs at either side of the harbor entrance are fully exposed to the waves, which, during the trade-wind season, beat upon them incessantly, while at the inner end of the harbor, which runs nearly at right angles to its outer portion, the water is calm, except in the most severe storms, and there is no evidence of any considerable damage, even under such extreme conditions. The numerous streams which enter the harbor cause considerable local differences in the salinity of the water and in the amount of sediment that it carries in suspension. The configuration of the shore-line is such that several sheltered coves are found near the harbor entrance, while off the headlands between these coves the reefs are exposed to strong currents and heavy breakers.

Only 6 species of Alcyonaria were collected at Tutuila, and of these 2 occurred so rarely that they constitute a negligible factor in the reef fauna. Of the 4 remaining species, *Alcyonium flexile* and *A. glaucum* can contribute to reef formation only after the death of the colony, as the spicules are borne free in the tissues. The colonies of *A. rigidum* and *A. confertum* form at their bases dense masses of coral rock composed of fused spicules. As the colony expands the tissues die about its base, and often in the center, so that the spicule rock is left exposed. In this manner masses of limestone 4 feet high and more than 20 feet in circumference are formed. Sometimes, due apparently to a stimulus to growth caused by the presence of boring mollusks or annelids in the dead skeletal portion of a colony of *Alcyonium*, columns are formed with an internal axis of spicule rock from 6 inches to 9 inches in diameter and extending 10 feet above the general level of the reef.

These 4 species of *Alcyonaria* differ very much as regards their distribution on the reefs. *A. rigidum* occurs only in deep water or in shallow places where strong currents provide a comparatively low temperature and an abundant supply of oxygen. *A. glaucum* has nearly as weak powers of resisting adverse conditions as the former species, but can live in somewhat more quiet water and is consequently found nearer shore and on less exposed portions of the reef. *A. confertum* is by far the most resistant species. It consequently occurs on all parts of the reef from near the shore at low-water mark to the deepest visible part of the vertical outer face of the reef. *A. flexile*, while able to withstand the conditions in shallow water, is never found in exposed places and is consequently the most restricted in its distribution.

The resistance of these species to high temperature corresponds closely to their resistance to unfavorable conditions in their natural environment. *A. rigidum* succumbs much sooner than either of the others, while *A. confertum* is by far the most resistant. The other two species stand near one another in an intermediate position as regards resistance to heat.

Although the least resistant of the 4 important species, *A. rigidum* is found to cover much greater areas than any of the others and contributes by far the greater amount to the upbuilding of these particular reefs. It is the only alcyonarian found abundantly on the most exposed reefs, where, in many instances, it carpets large areas of the vertical outer face of the reef. Since it grows so much more rapidly than any of the massive stony corals, the latter are covered up and killed by the alcyonarian, so that on many of the reefs

the outer wall bears few other living corals. Frequently large areas, barren of any living coral, were found to be surfaced with a layer of limestone from 3 to 18 inches in thickness, formed from the spicules of this species. Large areas of this material were also found underlying the raised lithothamnium ridge at the outer border of the reef. On the horizontal reef surface it is found abundantly only in locations removed from the heavy surf, but where there is still vigorous wave-action when the tide is low—a set of conditions found only on the outer portion of some of the less-exposed reefs.

A. confertum forms a nearly continuous carpet over large areas, often several acres in extent, on the horizontal surface of many of the more protected reefs. In such locations practically the entire reef surface for a depth of from a few inches to more than 3 feet is composed of spicule rock, as the alcyonium has crowded out all other species of coral.

The two remaining species do not form incrusting colonies, but occur scattered over the reef as circumscribed mushroom-shaped (*A. glaucum*) or shrubby (*A. flexile*) growths.

Several lines of squares, each 25 feet on a side, were laid out across different reefs, and the part of each square occupied by Alcyonaria was determined. Along these lines the Alcyonaria began from 50 feet to 400 feet from shore, depending upon the topography of the shore-line, and extended to the inner border of the lithothamnium ridge (about 50 feet from the edge of the reef), forming an almost continuous carpet over a considerable portion of the line.

Whether or not the Alcyonaria have in the past been as important limestone-forming agents on the Samoan reefs as they now are can be determined only after the examination of cores obtained from borings through the reefs. This part of the work, as well as the final measurements of several hundred specimens of Alcyonaria of all sizes to determine their growth-rate, must be completed at a later visit to this region.

That the conditions found on the reefs at Tutuila are not exceptional is shown by some observations of Dr. Carl Elschner, of Berkeley, California, who recently sent to me for determination specimens of two species of *Alcyonium* from Fanning Island, with the statement that this organism "forms fleshy and slippery masses covering a great part of the lagoon bottom," and that at least one-third of the surface rock at the bottom of the lagoon was composed of spicules of Alcyonaria.

Since this material is very rich in magnesium, as is also the coral laid down by the coralline algæ, it is quite possible that in some of the earlier determinations, where chemical analysis was relied upon for the identification of materials, the presence of limestone formed from these spicules has not been recognized for its full value.

Studies of Alcyonaria at Tortugas, by L. R. Cary.

Measurements and photographic records of the growth-rates of several species of Alcyonaria were continued from previous years. All of these specimens were transferred last season from their previous locations to the surface of a reef in 12 feet of water to insure uniform environmental conditions, since it had been observed that the average size of mature colonies was greater in deep than in shallow water. The results obtained this season indicate that in the deeper water the growing-period is extended, as several specimens which had been practically at a standstill for 4 years while on shallow reefs showed a measurable increase in size during the past year.

The resistance to heat in stony corals has been found by Mayer,[1] to correspond in general to their distribution on the reefs. Those forms which are

[1]Carnegie Inst. Wash. Pub. No. 183.

most resistant to increased temperature occupy the most exposed and shallowest portions of the reefs. The species most affected by increase in temperature are deeper-water forms not usually found on shallow reefs, in tide-pools, or where there is much sediment on the bottom. The distribution of the Alcyonaria on the reefs about the Samoan Islands was also found to be in accord with their powers of resistance to increased temperature.

When studied in reference to their heat resistance, the 12 most abundant species of Alcyonaria about Tortugas fall into several well-defined groups. *Pseudoplexaura crassa* and *Eunecia crassa* are unable to withstand a temperature of 34.5° C. for 1 hour; *Plexaura flexuosa, P. homomalla, Plexaurella dichotoma, Plexaurella* sp., *Eunecia rousseaui,* and *Muricia muricata* were killed by an exposure to a temperature of 35° C. for 1 hour; *Gorgonia flabellum* and *G. acerosa* were killed by exposure to 37° C. for 1 hour; *Gorgonia citrina* and *Xiphigorgia anceps* survive all temperatures up to 37.5° C.; while *Briareum asbestum* was not killed until a temperature of 38.2° C. was maintained for 1 hour. The temperature range of the Alcyonaria is thus practically identical with that of the Madreporaria.

On the shallowest portions of some of the reefs about Tortugas the temperature of the water during the hottest days in summer, when low tide comes late in the afternoon, frequently rises to that which is fatal to all of the Alcyonaria studied. On any reef where there is an active circulation of water the temperature has never been observed to reach that fatal to the least-resistant species for periods of sufficient length to cause their death. The temperature effect is therefore of very narrow application on the reefs about Tortugas. Even when, as sometimes happens, the distal portions of alcyonarian colonies are exposed to the air for a considerable time, it is seldom fatal to the species having a loose-tissue structure. On some of the shallowest reefs mature specimens of none but the most resistant species are found, while small specimens of the less resistant forms are sometimes abundant, but in other seasons are almost entirely absent. These facts may perhaps be accounted for by the destruction of the less resistant species because of the high temperature of the water, although other factors can not be excluded when these reefs are visited at intervals of a year and at practically the same season each time.

The oxygen consumption of colonies of the same species was found to be directly proportional to the mass of living tissues in a colony and to vary only slightly with the physiological state of the specimen. A colony in which each polyp was in full expansion did not respire any more rapidly than did the same colony when its polyps were kept withdrawn within the cœnenchyma because of the rotation of the jar within which the experiment was being carried out.

The oxygen consumption per gram of living tissue per hour varies for different species from 0.0139912 c.c. (*Briareum asbestum*) to 0.07459 c.c. (*Gorgonia flabellum*). There was found no apparent correlation between the activity of metabolism and resistance to heat. The least-resistant forms have an intermediate respiration-rate; the most-resistant species has a very low respiration-rate; while the species of the genus *Gorgonia,* which constitute a group of highly resistant forms, have the most rapid metabolism. Although there was no constant difference in the respiration of the same specimen when its polyps were contracted or expanded, in spite of the fact that in the last-named condition the surface area was increased to 1.5 times that of the former, a high respiration-rate was observed in all those species in which the area was greatest in proportion to the mass of the colony. The relation between the values of the constant a/w (area divided by the weight) for the several species was prac-

tically the same as that for respiration, showing that some spatial relations between the different tissues is an important factor in determining the rate of metabolism.

Studies on the Metabolism of Cassiopea, by L. R. Cary.

In studying the metabolism of *Cassiopea* the oxygen consumed was determined by Winkler's method. The experimental specimens were kept in jars of known capacity provided with clamped tops fitting on rubber gaskets, so that no interchange of gases was possible. During any experiment the jars were kept in a large tank of sea-water which was covered with a light-tight cover, a precaution due to the presence in the tissues of the medusa of zooxanthellæ which give off oxygen in the presence of sunlight. The temperature of the water did not vary more than 0.1° during the course of any experiment.

From the structure of the Scyphomedusæ it is apparent that the greater part of their respiration must take place through their ectodermal epithelium, since the endodermal epithelium is of relatively small area and the mesoglœa but a structureless secretion formed by the activity of the epithelia. Moreover, the muscles are entirely of ectodermal origin and the other most active type of cells—the unicellular glands—are most abundant in the ectoderm. The oxygen consumption ought, therefore, to be most closely correlated with the area of ectodermal tissue. The surface area of an entire medusa is especially difficult to calculate, but that of a medusa disk can be determined as the areas of two equal circles—the exumbrella and subumbrella. It was also found that the relation between the diameter and the weight of any disk is represented very closely by the formula $d = 328 \sqrt[3]{w}$. Since the body of a cassiopea is more than 95 per cent sea-water, no correction was made for the amount of water displaced by the specimen.

As in my earlier studies on the physiology of *Cassiopea*, it was found that the individual variations in metabolic activity were so great that reliable comparisons could not be made between different individuals. Safe comparisons could be made only by using the same specimen in several experiments or by using parts of the same individual in any single experiment.

The oxygen consumption of entire medusæ, taking the average of 20 experiments with specimens of various sizes, was 0.03896 c.c. per gram per hour; that of the disks after the removal of the mouth-arms and stomachs was for the same specimens 0.04216 c.c. per gram per hour. The average weight of the entire medusæ was 79.95 grams; that of the disks 28.05 grams. The actual average oxygen consumption of the entire medusa was 0.972 c.c. per hour; that of the disks 0.41 c.c. per hour.

In a series of experiments devised to determine the respiration of the different tissues of the disk, it was found that taking the respiration of an actively pulsating half-disk as 100, the active muscles used 36.15 parts, the epithelia (and inactive muscles and nerves) 57.48 parts, the nerves and sense organs 1.37 parts, and the mesoglœa 5 parts.

That the mesoglœa, although making up so much of the bulk of the body, is relatively inactive is also shown by the fact that when a comparison is made between the two halves of a disk, one of which has been split horizontally, thus exposing to the water two surfaces of mesoglœa nearly equal in extent to the external epithelial areas, the respiration is only slightly increased.

The epithelium of the exumbrella consumes 60.5 per cent as much oxygen as that of the subumbrella, when the muscles in the latter are inactive. This figure represents, as accurately as it could be determined, the ratio between the weights of the ectodermal cells covering the two surfaces. Excluding

muscular activity, the respiration appears to be directly proportional to the mass of tissue, as was shown to be true of the Alcyonaria.

In experiments where actively pulsating half-disks were compared with halves of the same disks which were rendered inactive by the removal of their sense-organs, the average oxygen consumption of all the active halves was 1.8192 c.c. O_2 per hour; that of the inactive halves was 1.1367 c.c. O_2 per hour. When active halves were compared with their mates in the muscles of which a circuit wave of contraction was maintained the oxygen consumption was 2.1034 c.c. for the active specimens and 2.041 c.c. for the activated specimens. In these last-mentioned experiments several half-disks were frequently put into each of the jars, so that no comparisons based upon these figures can be drawn between the two sets of experiments.

With the more accurate determinations by the Winkler method than was possible with the colorimetric method of measuring the metabolism that was used last year, it was found that in 4 of the 20 experiments the activated halves were respiring more rapidly than their normally pulsating mates, and that in 5 experiments the respiration was the same for both sets of half-disks. In these 9 experiments the activated half-disks were pulsating from 3.5 to 5 times as rapidly as those with sense-organs. When a labyrinth of 8 sections was made in the tissues of the activated specimens, so that their pulsation-rate was only from 1.2 to 1.7 times that of the halves under the control of the sense-organs, the respiration of the former was 66 per cent that of the latter.

When a number of series of half-disks of the two last-mentioned types were kept for several days and the metabolism determined each day it was found that the differences in the rate of metabolism became progressively smaller and smaller, as was true of the differences in the rate of regeneration or loss of weight during starvation, as determined in previous experiments.

In all cases where it was carefully determined, the respiratory quotient varied from 0.82 to 0.94. At first this value was not constant even for the same disk from one experiment to another, showing that different sorts of materials were being oxidized from time to time. In any long-continued experiments, however, the respiratory quotient reached a practically constant value after the tissues of the body, chiefly the mesoglœa, were being consumed. This constant value was lower than that obtained in experiments carried out on disks shortly after they had been brought into the laboratory when some of the natural food-material would still be present in the gastral canals. A similar condition was recorded by Mayer and by Hatai in studying the loss of weight during the starvation of *Cassiopea*, both of whom observed that the results for the first day of starvation were unreliable on account of the differences in the rate of starvation due to varying amounts of food in the gastral cavity.

On the Condition of the Albino Rats on East Key and Garden Key in the Dry Tortugas, by S. Hatai.

In the season of 1916, Dr. Donaldson reported on an "Experiment on the Feralization of the Albino Rat," 8 animals having been placed on East Key in the summer of 1914. Six of these animals were recovered in 1916, but the effect of the wild life on the relative weight of the nervous system could not be studied on this material.

In July 1916, 30 pairs of albinos were released on East Key, and 11 males and 13 females on Garden Key. All of these were about 100 days of age and were ear-marked. During the present season (1917), I endeavored to determine whether (1) these rats had lived through the year; (2) had been able to breed; and (3) whether they showed any significant modifications in the relative weights of the central nervous system or the ductless glands and the gonads.

No albinos were recovered from Garden Key.

From East Key, between June 29 and July 22, 7 albinos (2 males, 5 females) were obtained; 2 were killed in capture and only the body measurements of these could be obtained; 5 were taken alive, and for these the body measurements and the weights of the brain, spinal cord, the several ductless glands and the gonads were recorded. These results showed that some of the 60 rats (30 pairs) placed on East Key in 1916 had survived. Among the 7 there were 2 small animals (body-weights 36 gm. and 56.7 gm.) which were not ear-marked. These must have been born on the key. The 1916 rats therefore bred during their stay on the key.

Our third question relates to the weight of the central nervous system and some of the other organs.

Before the rats were released last year, a sample series of 3 males and 3 females was examined for the weights of the several organs. In these animals, which we assume to have been similar to those released, the brain was 2 per cent heavy, the cord 3 per cent light, while the suprarenals were heavy, the gonads somewhat heavy, and the thymus and thyroid very light.

In the 5 captured rats examined for the weights of the organs, the relative weight of the brain was found to be 6 per cent and of the spinal cord 4 per cent above the standard values for albinos of the same body-lengths, while the weight relations of the ductless glands and gonads corresponded to those of the rats when released. In this series of 5, 1 rat had been born on the key, but the values for the organs in this animal stood in the same relation to the standard values as in the case of the other 4. Characteristic of all the rats was the very small weight of the thyroid gland. Our main interest in these results is connected with the relative weight of the brain and spinal cord. In all of the 5 cases the brain-weight found was higher than that to be expected, while in 4 out of the 5 cases the same was true for the weight of the spinal cord. Apparently life under wild conditions tends to increase the relative weight of the central nervous system, even when the rat is 100 days old before being subjected to the new environment.

The conditions on East Key are severe. Rain and dew are the only sources of fresh water, yet one captured rat refused to drink when fresh water was offered to it. The main food-supply seems to be sea-oats and the ocypoda crabs, both of which were found much reduced in quantity this summer as compared with last summer.

The old rats (5 in number) all had infected lungs; the 2 young rats sound lungs.

The rats were tame, in the sense of not fearing man, so that several were caught with a butterfly net. On the other hand, the two males, when put together, fought savagely.

There is no reason to think that the supply of these rats on East Key has been exhausted, and possibly a later visit to this key will reveal full-grown descendants of the original lot. It is in these descendants that we should expect to find more clearly marked the effects of feralization if this condition really produces definite modifications.

The Brain Weight of the Gray Snapper, Neomænis griseus, of Different Body-lengths; and also a Determination of the Various Nitrogenous Extractive Substances in the Brain, by S. Hatai.

The primary object of the present investigation was to extend some observations made on the central nervous system of the albino rat to the nervous system of lower vertebrates. There has been much speculation from time to time by various writers concerning the metabolic activity of this important

organ, but in the absence of the necessary information the conclusions have been unsatisfactory. Recent advances in biochemical technique now enable us to make precise quantitative determinations of the various chemical components in the nervous system, and it was the hope of the present writer to obtain data which would assist in a comparative study of the metabolic phenomena in the nervous system of vertebrates.

The gray snapper was chosen for this investigation not only because these fishes are abundant in subtropical seas, but also because they afford numerous advantages for experimental purposes. The snapper may be kept in the laboratory for a long period, and, in captivity as well as when free, takes almost any kind of food, cooked or raw, animal or vegetable. The fish is well known for sagaciousness and boldness and thus is suited for various kinds of experimentation. Indeed the snapper has already been carefully studied by Reighard (1908) as to its behavior.

Altogether 44 snappers of medium size were used for the purpose of determining the various extractive nitrogenous substances in the brain. These brains were divided into three samples, each giving approximately 10 grams of moist brain-weight. The brains were ground finely and then preserved in 150 c.c. of a 2.5 per cent solution of trichloracetic acid in water. The filtrates from this mixture have been brought back to the Wistar Institute for analysis. I am of course unable to make any statement concerning the metabolic state of the brain of this interesting fish until the analysis has been made, which may take several months.

In addition to obtaining the material mentioned, I have determined the water-content of the brain from 64 snappers having various body-lengths (90 to 450 mm.). These brains also furnish material for the relative amount of the lipoid and non-lipoid fractions—a relation to be contrasted with that found in mammalian brains. This study also requires several months for the completion of the analysis, and at this moment I wish merely to express my great satisfaction at being able to accumulate such valuable material.

The Brain-weight in Relation to Body-length.

The mathematical formula which enables one to estimate the probable brain-weight in relation to body-length or body-weight has been determined in the case of albino rats and it has proved highly useful when determining the more or less minute changes in the brain under various experimental conditions.

With the hope that the gray snapper may in future prove to be a suitable form for certain lines of experimental work, I have utilized all the brains which have been used for the chemical investigation, together with some others, for study of the growth of the brain in weight with respect to body-length. Altogether observations on 74 brains of the gray snapper have been recorded. It is to be regretted, however, that the material, though amply sufficient for the fish which are more than 200 mm. long, contains very few (only 3) measurements for fish below 200 mm. Thus I am unable to make a study for the earlier phases of the growth of brain in weight, but I feel safe in stating that in fish over 200 mm. in length the relation between brain-weight and body-length is linear and thus can be expressed by a very simple formula. I may say that the fishes which are less than 200 mm. long are considered to be very small, while those measuring more than 300 mm. are regarded as large. A most careful search was made to find small snappers, but without success. It is probable that the fry of the snapper may not live in the open sea or along the beach, but may be hiding under the intricate roots of mangroves, trees

which are not found at Tortugas. It is the hope of the writer to obtain in the future a sufficient number of the small snappers for the completion of this investigation.

In this preliminary report I shall present merely the average of the brain weights in order to indicate their magnitude for fishes of different sizes.

Mean weights of the fresh brain in the gray snapper, Neomænis griseus, according to body-length.[1]

Body-length.	Brain-weight.	No.	Sex.
mm.	*grams.*		
200 to 250	0.643	10	Combined.
250 to 300	0.860	23	Do.
300 to 350	1.037	15	Do.
350 to 400	1.296	12	Do.
400 to 450	1.513	11	Do.

[1]Body-length = Tip of snout to middle of tail.

I have also determined the brain-weights of several other kinds of fishes, but the data so far obtained are too scattered to justify their publication at this moment.

Changes in the Composition of Cassiopea xamachana during various periods of Starvation, by S. Hatai.

In my previous work on the changes in the composition of *Cassiopea xamachana* (1917) it was found that at the end of 25 days of starvation the absolute amount of nitrogen in the starved *Cassiopea* was considerably higher than in normal specimens having the same body-weight. It was noted also that, although high when compared with a normal specimen equal in weight to the starved animal, it was very low for the initial body-weight of the starved animal. From this it was inferred that the nitrogen had also been consumed during the period of starvation.

Since the above conclusion was reached by comparing two different series of individuals, one starved and other not starved, and since the two series might possibly be dissimilar in respect to their nitrogen content, it was thought desirable to modify the experiments by starving one half of each specimen, while the other half was utilized for control. We hoped thus to avoid a possible error which might arise from individual peculiarities. Furthermore, it was the object of the present experiment to determine the changes in the composition during various stages of the starvation, since in this way we might obtain a much clearer notion of the rate of nitrogen change accompanying the different rates of reduction in the body-weight.

All together 15 cassiopeas were taken. These were divided into 5 groups, each group containing 3 individuals, and were starved for various periods—3, 7, 14, 21, and 25 days. In each case, one half of the medusa was subjected to starvation, while the other half was examined at the beginning of the experiment. The mode of the starvation was similar to that in the previous study—that is, the sea-water was doubly filtered to remove all trace of the micro-organisms, and the medusa which was to be starved was kept in such water. The water was changed once a day throughout the period of starvation. The test animals were weighed but twice, at the beginning and at the

end of the experiment, instead of several times during starvation. Thus these medusæ received less severe treatment in the course of the experiment than those previously studied.

All the cassiopeas here used were dried at a temperature of 80° to 90° C. for a week and then later dried at the Wistar Institute under better laboratory conditions. The object of this was to determine the water-content as well as the nitrogen-content of the dried substance before and after starvation.

Since the present work is still incomplete, I am unable to make any statement concerning the detailed results, and therefore I shall limit myself to two general conclusions:

(1) The rate of the reduction in body-weight during starvation is nearly identical in both the present and the previous study (1916). It appears, therefore, that whether starvation is performed on the entire or on the half body the results are similar, so far as the rate of reduction is concerned.

(2) The water-content of the body was identical in both the starved half and the control half, both giving on the average 94.94 per cent.

An attempt was made to determine the growth of *Cassiopea* in weight and in the diameter of the disk in respect to age. For this purpose 9 small cassiopeas, ranging in body-weights from 0.12 to 1.20 grams, were placed in a wire cage, the bottom of which had been covered with coral sands taken from the place where the cassiopeas were abundant. This wire cage was submerged in the lagoon of Garden Key, on the collecting-ground of the medusæ. Unfortunately a storm which occurred 10 days after this experiment was started washed away the cage and the cassiopeas were lost. It was determined, however, that cassiopeas made an average of 31 per cent increase in body-weight at the end of one week.

A second experiment was begun, using cassiopeas of different sizes, also placed in a wire cage in the lagoon. However, the location this time was evidently not suited to their growth, though the place was perfectly safe from storm, and so two weeks later the medusæ were found to have lost in body-weight to the extent of 20 per cent on the average. Thus these studies ended in failure. The problem of the body-growth in respect to age is fundamentally important, and it is therefore the hope of the present writer to be able to pursue this study at some future time.

Report of Observations and Experiments upon the Biological Significance of Animal Coloration and an Extension of the Field of Color-Photography, by W. H. Longley.

In continued prosecution of studies previously reported, I worked at Tortugas from June 8 to August 13, 1917. During that time effort was expended upon three undertakings: (1) to secure photographs of fishes in different color phases and engaged in different characteristic activities noted in preceding seasons; (2) to test the possibility of demonstrating by color-photography to what extent their colors repeat those of their environment; (3) to determine the meaning of certain variations in color which I had observed earlier in Brachyura.

In the attempted achievement of the first two objects the essential apparatus consisted as before of a submarine camera and diving hood. A 4 by 5 Auto-Graflex replaced the No. 0 Graphic camera used during the preceding summer. This was fitted with a Bausch & Lomb, Tessar lens, series Ic, f. 4. 5, suitable for an instrument taking a plate 5 by 8 inches in size. Its container was water-tight, neither excessively large nor heavy, and so could be carried about conveniently upon the bottom. By means of plungers and screws

protected by stuffing-boxes it allowed one to focus accurately upon desired objects and to make either instantaneous or time exposures. The complete apparatus worked well; some desirable pictures were secured, and the possibility of successful submarine photography in colors was established.

In this connection I desire particularly to express appreciation of the privilege I enjoyed in being permitted to work at Tortugas for two weeks after the close of the regular season, which alone made it possible to attempt color-photography this year. For invaluable assistance rendered me throughout the whole period I am deeply indebted to Mr. John Mills, laboratory engineer, who voluntarily remained with me until my work was completed.

No sustained effort was made to collect additional evidence affecting the conclusion already drawn, that the coloration of tropical fishes is obliterative in its general effect. Such evidence, however, has continued to accumulate.

The red goatfish (*Upeneus maculatus*), which is commonly seen over sandy bottom in a gray phase with three lateral brown spots, turns green among turtle-grass, or becomes striped or banded with reddish brown when its surroundings are dark-colored. The common grunt (*Hæmulon plumieri*) has a dark-brown phase consistently exhibited when it is schooling among such brown corals as *Orbicella*, yet is exceedingly pale when resting over bare white bottom or straw-colored *Palythoa*. The schoolmaster (*Neomænis apodus*) makes appropriate adjustment to a brown or gray environment. Additional adaptive color-phases or hitherto unnoted ability to change color have also been observed in *Calamus arctifrons*, *Lachnolaimus maximus*, *Neomænis analis*, and *Ocyurus chrysurus*.

Two additional green species have been seined on the grass-flats. Since one, as yet unidentified, was represented by several specimens, and the type specimen of the other (*Doratonotus megalepis*) was taken in the same way in similar surroundings, it is probable that both occur normally in such places. This fact emphasizes anew the remarkably high degree of correlation already demonstrated between the occurrence of this color upon fishes and in their environment.

It has been noted in a preceding report[1] that field observations do not support the hypothesis that specific phases of coloration are associated with different activities. It is quite true, nevertheless, as has been stated by Dr. Charles H. Townsend,[2] that in a number of species different color phases may be observed in individuals according as they are in motion or at rest. The differences in such cases seem to be primarily in pattern, although the creatures' shade may be incidentally affected and doubt be raised concerning the efficiency of the control exercised over it by that of their surroundings. This is especially true when dark bands appear upon a light-colored fish as it comes to rest in the open on sandy bottom, but it has been demonstrated repeatedly that amid dark surroundings such resting-phases are darker than under other conditions.

The tendency for transverse bands to replace longitudinal stripes or self-color when swimming specimens come to rest on or near the bottom is very striking. It appears more or less regularly in *Calamus arctifrons*, *Epinephelus striatus*, *Iridio bivittatus*, *Lachnolaimus maximus*, *Neomænis analis*, *Sphyræna barracuda*, and *Upeneus maculatus*. I am not aware of any instance in which the reverse change occurs under the same conditions during daylight. Whether or not the idea is entertained that banded patterns are more effective

[1]Carnegie Institution of Washington, Year Book, No. 14 (1915), p. 208.

[2]Townsend, C. H.: Observations on instantaneous changes in color among tropical fishes. Thirteenth Annual Report N. Y. Zool. Soc., 1909.

than those they replace in reducing the visibility of inactive fishes, the facts noted, and others, suggest very plainly that existing color-patterns in animals, no less than their colors themselves, are not a product of haphazard, uncontrolled mutation; for it is improbable that fixed colors and patterns are without biological significance, when changeable ones commonly vary according to a definite system.

The observations upon Brachyura refer to the prevalence of color changes within the group, the causes which determine them, and the conditions under which they occur in nature.

With respect to the first point, it may be inferred that changes in color do not occur uncommonly within the limits of the suborder, although they have apparently been reported in only two species. To these, *Gelasimus* sp. and *Ocypoda arenaria*, may be added *Portunus depressifrons*, *P. sayi*, *P. spinicarpus*, *Callinectes ornatus*, *C. marginatus*, and *Euryplax nitida*.

It seems clear, in addition, that both in the laboratory and in nature the fundamental factor in determining the shade of exposed specimens is that of the substratum on which they stand. This is at variance with the conclusion deduced from his study of *Ocypoda* by Dr. R. P. Cowles,[1] but is indicated by the following facts:

In the subdued light of the laboratory, at a temperature of 30° C., for example, individuals of the species mentioned above, with the exception of the Brazilian *Gelasimus*, become dark or light respectively in uncovered black or white dishes of sea-water. In addition, specimens of *Ocypoda*, the form experimented upon most extensively, having stood long enough to be adapted in color to their situation, may be cooled in white dishes to 12° C. or lower or warmed in dark ones to approximately 35° C. without changing in coloration under the treatment. Again, if crabs are placed in black and in white dishes of sea-water and permitted to adjust their coloration to their surroundings, after the light one has been cooled and the other warmed, each in its own vessel, upon being transposed they will readjust themselves and reverse their original relation in the face of a temperature difference which should make this impossible if temperature were the basic factor in determining their shade.

The temperature difference involved in the last experiment may be so great that there can be little doubt of the significance of the result. In one instance, while the double change was being accomplished, the water in the cooler dish neither rose above 17° C. nor fell below 35° C. in the other. The time required for the two crabs to attain the same shade in this case was 29 minutes and the reversal of the original relation was completed in about 50 minutes. These records, however, convey a false idea of the rate at which such changes commonly occur, for the water in the warmer vessel was for a time above the temperature at which a true heat-blanching is induced. Half or even one-third of the time indicated commonly suffices for the making of such adjustments in young specimens whose changes are most evident.

In *Callinectes marginatus*, at least, such adaptive changes in shade as have been noted occur in nature. When one walks in the shallow water along beaches where this species is found, the individuals that dart away from under foot are dark or light, according as they spring up from dark or light patches. It is to be anticipated that similar adjustments are made by the other changeable species.

[1] Cowles, R. P.: Habits, reactions, and associations in *Ocypoda arenaria*. Papers from the Tortugas Laboratory, Carnegie Inst. Wash. Pub. No. 103, pp. 1–41, 1908.

The idea that the prevailing temperature at Tortugas is so high that heat-blanching would necessarily follow and the possibility of adaptive reaction be limited thereby, is due to a misconception of the facts. A thermometer lying on the sand, say 25 feet above high-water mark, will frequently record a temperature above 45° C. It is not, however, in that zone that the crabs are to be observed, but much lower upon the beach. Moreover, their bodies are not on the sand, but above it. If one uses the thermometer with these facts in mind, the case assumes an entirely different aspect.

At 2^h45^m p. m. on August 10, 1917, the temperature recorded by a thermometer lying on the sand about 25 feet above high-water mark on the beach at Tortugas was 49° C. When the instrument was elevated half an inch upon two crotched sticks the mercury fell to 40° C. In the middle of the exposed zone below high-water mark the corresponding temperatures were 39° C. and 37° C. respectively. The latter is at the most not more than 2° above the point where on the average heat-blanching becomes evident. Up and down the whole length of the beach, where earlier or later in the day large numbers of the creatures might be seen feeding or running actively about, only 5 were visible when these observations were made. These were all digging or lying in the mouths of their burrows. Hence it is apparent that the range of *Ocypoda* is so restricted and that its activities vary to such an extent during the day that when and where it freely exposes itself there is no known factor which necessarily limits its theoretically advantageous color adjustments.

The facts established concerning the color-changes of Brachyura show among other things how closely a creature's habitat must sometimes be defined before there is any possibility of comprehending its degree of adaptation to its environment. In view of what has been learned regarding the coloration of fishes[1] they are particularly significant, however, because of their suggestion that the coloration of crabs conforms to the same general laws.

On the Non-Existence of Nervous Shell-Shock in Fishes and Marine Invertebrates, by Alfred Goldsborough Mayer.

Experiments made at Tortugas during the summer of 1917 indicate that the nervous systems of fishes and invertebrates are remarkably resistant to the injurious effects of sudden explosive shocks. Many experiments were made upon the Scyphomedusa *Cassiopea xamachana*. The medusæ were paralyzed by removing their marginal sense-organs, and then a ring-shaped strip of subumbrella tissue was set into pulsation by an induction shock, thus producing a single neurogenic contraction which travels through the circuit-shaped strip of tissue at a uniform rate of speed, provided temperature, salinity, and other factors remain unchanged. It is thus possible accurately to ascertain not only the rate of nerve-conduction, but also the peculiar individual characteristics of the wave in each pulsating ring.

These rings were placed in a light silken bag immersed about 10 feet below the surface of the sea and a half stick of dynamite was exploded within 3 feet of them. This, however, produced no effect, either upon their rates or the character of their pulsation waves, although fishes possessing swim-bladders were killed within 10 feet, and within 20 feet of the exploding dynamite were injured so that they turned ventral side uppermost.

When the pulsating rings were placed in glass jars or tin cans, partly filled with air, the containers were crushed or shattered by the explosion and much

[1] Longley, W. H.: Studies upon the biological significance of animal coloration: I. The colors and color changes of West Indian reef-fishes. Jour. Exp. Zool., vol. 23, pp. 536–601 (1917).

mechanical injury was sustained by the medusa rings, which, however, could at once be restored to normal pulsation by an induction shock if their pulsation had ceased. It was also observed that the lacerated area regenerated at a normal rate.

Professor J. F. McClendon suggested that fishes with swim-bladders might prove to be more sensitive to explosive shocks than those without swim-bladders, and experiments showed that a half stick of dynamite may be exploded within 3 feet of a small shark, which has no swim-bladder, without producing any apparent injury. This also applies to such teleosts as lack swim-bladders. Dr. S. C. Ball kindly dissected some of the fishes with swim-bladders, which had been killed by the explosions, and found that the swim-bladder had burst and the tissues were crushed in around it, often breaking the vertebral column of the fish. Moreover, Professor W. H. Longley, who has had much experience in the use of dynamite, tells me that echinoderms and crustacea, if not mechanically torn apart, show no apparent ill effects, but nevertheless, move away from the site of the explosion.

It appears, then, that the nervous system of these lower forms is extraordinarily insensitive to shock due to explosion of dynamite and that the injurious effects of the explosion if present are due to mechanical laceration of tissues and especially the crushing inward of air-filled cavities. It seems possible, therefore, that the cavities of the middle ear and eustachian tubes may be a means of danger to men standing near exploding shells.

It has been suggested that the sudden reduction in atmospheric pressure in the close proximity of an exploding shell might set free dissolved gases in the blood and elsewhere, thus vacuolating the tissues and producing pressure and other effects upon the nerves; but our experiments with pulsating rings of *Cassiopea* seem opposed to this hypothesis, for no injurious effects other than those of simple asphyxiation were produced by sudden exhaustion of the air surrounding the animals, and recovery, when replaced in normal sea-water, was almost immediate.

These results are in accord with the conclusions of Grasset (1915), Eder (1917), Babinski et Froment (1917), and others, that "war-shock" is allied to hysteria and is a psychological rather than a physiological phenomenon.

Efficacy of Holothurians in Dissolving Limestone, by Alfred G. Mayer.

No one appears to have attempted to evaluate the effect of holothurians in dissolving limestone until, in the summer of 1917, an experiment was made upon *Stichopus möbii* at Tortugas, Florida. A specimen, 210 mm. long and 70 mm. wide, was kept for 2 months in a rectangular glass tank 68 cm. long by 30.5 cm. wide and containing sea-water flowing constantly through it so as to maintain a uniform depth of about 5 inches. The bottom of this tank, which was 2,074 sq. cm. in area, was covered with 3,447 grams of limestone sand taken from the reef-flat upon which this species of holothurian is abundant. The sand consisted chiefly of fragments of *Halimeda* together with broken coral and pieces of molluscan shells.

Between June 3 and 25 the holothurian swallowed very little of the sand and appeared to be extremely sensitive, contracting whenever the tank was shaken or anyone came near it. Moreover, the tank was kept in the diffuse light of the laboratory, and this dull light seemed to inhibit the activities of the animal. Accordingly, on June 25, the sand was removed and reweighed and found to have lost none of its weight. It was then replaced in the tank and the tank placed in the sunlight in a region where shocks and jars were infrequent. The holothurian at once began to swallow large quantities of sand as in nature, about 25 grams passing through it every 24 hours.

On July 25, after the sand had been swallowed for 30 days by the holothurian, it was found that 380.5 grams had disappeared, being dissolved by the acidity of the alimentary tract of the holothurian; and as the specific gravity of the sand was 2.43 it appears that about 156 c.c. of sand had disappeared. Thus these animals may be quite efficient in deepening lagoons over the limestone floors of which they are abundant.

Other experiments showed that large holothurians, such as *H. floridana*, at Tortugas, Florida, may defecate from 72 to 94 grams of sand (dry weight) per 24 hours. Also, when full of sand, the fluid of their alimentary tract is usually alkaline and about 7 P_H, but when the animal is empty the fluid usually becomes quite acid, ranging from 4.75 to 7 P_H. Thus it seems that the presence of limestone sand in the guts reduces the acidity of their fluid, as would be expected were the sand dissolved by the acid.

We may conclude that holothurians are a significant factor in causing limestone to disappear from the floor of reef-flats, one holothurian, such as the specimen experimented upon, destroying about 1,870 c.c., or 114 cubic inches of limestone per annum.

Death from High Temperature due to Accumulation of Acid in the Tissues, by Alfred Goldsborough Mayer.

I find that there is a converse relation between the rate of oxygen consumption in reef corals and their ability to resist high temperature, those corals which are most readily killed by heat having the highest metabolism (rate of oxygen consumption).

Name of coral.	Constant temperature exposure to which causes death in 1 hour.	Relative rate of oxygen consumption per gram of living substance in each coral.
	°C.	*c.c.*
Acropora muricata...	34.7	18.7
Orbicella annularis...	35.6	6.1
Mæandra areolata...	36.8	5.5
Favia fragum........	37.05	3.8
Siderastrea radians...	38.2	1.0

Also, if sea-water be supersaturated with carbon-dioxide gas, the toxic effect is in the same order as that of high temperature. That is to say, those corals which are readily killed by heat are also correspondingly easily killed by H_2CO_3.

This toxic effect of carbon dioxide is not due to its replacing some of the oxygen of the sea-water, for I find that corals are remarkably insensitive to a reduction in oxygen-supply, all species except *Acropora* living more than 11 hours in sea-water, under an air-pump which reduced the oxygen to less than 5 per cent of that of normal sea-water; and even *Acropora* can withstand 6 hours of this treatment.

We know, indeed, from the studies of M. Henze, that sea-anemones use less oxygen the less its concentration in the sea-water, and in 1917 J. F. McClendon found that the medusa *Cassiopea* can survive without apparent injury for more than 7 hours in the absence of oxygen, and during this time does not give out CO_2. Thus these cœlenterates can temporarily suspend their metabolism for a protracted period if oxygen be absent.

Winterstein's theory that death from heat is due to asphyxiation appears to be refuted by these experiments.

E. N. Harvey (1911) found that if the sea-water be heated the rate of nerve-conduction in *Cassiopea* augments in a right-line ratio up to a certain point and then rapidly declines just before death ensues.

In 1917 I found that this temperature curve, up to its maximum point, has no time-factor. That is to say, the rate at 35° C. is the same whether the medusa be placed at once in 35° C. or warmed slowly for several hours until it arrives at this temperature. Moreover, the normal rate for 29° is regained almost immediately when the medusa is replaced in this normal temperature. But when the rate is declining, on account of injuriously high temperature, I find that a time factor is involved, the decline becoming more pronounced as the heat is continued. Also, if after this the medusa is replaced in sea-water of 29° C., its former rate is much reduced and may never be recovered, although if exposure to the heat was not too long or the heat not too excessive, a slow recovery is usually observed, so that after a few hours the rate may again become normal.

It will be recalled that Harvey (1911) advanced the theory that some enzyme might be destroyed by the excessive heat, and being essential to nerve-conduction its loss caused the rate to decline. It seems now probable, however, that in excessive heat carbon dioxide accumulates in the tissues faster than it can be eliminated. It is easy to see how an acid of this sort might be eliminated and the rate gradually restored when the animal is replaced in cool sea-water, whereas if an enzyme were destroyed it might not so readily be replaced.

In any event, the theory of the toxic effect of uneliminated acid seems more in accord with the facts than does Winterstein's asphyxiation theory or the theory that death from heat is due to coagulation of proteid substances.

Death occurs at too low a temperature for coagulation in most if not all proteids; and, when killed, the animals are fully relaxed, as shown by Harvey. Moreover, coagulated proteins could not readily be eliminated when the animal was restored to water at normal temperature.

Report on Experiments made at Tortugas in 1917, by J. F. McClendon.

Metabolism of Cassiopea xamachana.

It was found that the metabolism of *Cassiopea*, as indicated by the heat produced, CO_2 eliminated, and oxygen consumed, was increased when more oxygen was added to the sea-water and decreased when part of the oxygen was removed from the sea-water. No oxygen is consumed and no CO_2 given off if no oxygen be present, yet the animal survives more than 7 hours in this condition. This was also true when only the umbrella of the cassiopea was used. It was found that the metabolism of the mesoglœa is practically zero, and therefore all the metabolism of the umbrella takes place within less than a millimeter of the surface and the effect of diffusion of oxygen into the cells on the metabolism is correspondingly small. The pulsations of the umbrella circulate the sea-water, and hence every cell is as close to the circulating medium as is the case with an animal with a circulatory system. The effect of oxygen concentration on metabolism is not due to diffusion phenomena especially limited to this type of animal, and we may assume that the results are of general significance in physiology. The direct application of these results to man would be the possible effect of the activity of the respiratory and vasomotor centers on the so-called basal metabolism.

Effect of Stretching on the Rate of Nerve-Conduction in Cassiopea.

Stretching has no effect on the rate of nerve-conduction in *Cassiopea;* that is to say, if it requires 1 second for the nerve-impulse to traverse a strip of umbrella of unit length, 2 seconds are required if the length is doubled by stretching. Owing to hysteresis, time must be given for adjustment to new conditions after change in length. The rate of the nerve-impulse corresponds to about 400 mm. of subumbrella tissue per second at 30°.

The Equilibrium Between Sea-Water and Calcite or Aragonite Crystals.

The solubility of $CaCO_3$ in salt water depends chiefly on the total CO_2 content, but this is difficult to measure directly. The total CO_2 affects the hydrogen-ion concentration, P_H, and this may be determined colorimetrically. In order to simplify nomenclature, sea-water is regarded as a mixture of water, neutral salts, CaO, and CO_2. The CaO may be titrated while boiling to remove the CO_2 liberated by the acid used in titration. Sea-water was shaken with calcite crystals at 30° until equilibrium was reached and the P_H and CaO (as carbonate and bicarbonate) were determined. A curve was plotted showing the relation of P_H to CaO. Aragonite gave the same curve within the limits of error. Sea-water is supersaturated as regards calcite and aragonite. No equilibrium was obtained by shaking the precipitated calcareous mud of Tortugas with sea-water.

Local and Diurnal Changes in Sea-Water.

Sea-water was studied at various locations at Tortugas and between Tortugas and New York. Determinations were made of temperature, Cl, CaO, CO_2, CO_2 tension, O_2, and P_H. The only diurnal change detected in the axis of the Gulf Stream was 1° in temperature. Marked diurnal changes were noted at Tortugas in water of 6 fathoms or less depth over populated bottoms. All shallow water of considerable area had some portions of the bottom populated, and the only shallow water not showing marked diurnal changes was associated with a tidal current flowing from deep water near at hand. Extremes were noted in the water between dawn and about 3 p. m. local time, the temperature and O_2 content being lowest at dawn and the CO_2 content being lowest at about 3 p. m. At about 3 p. m. the P_H is most favorable for the precipitation of $CaCO_3$, and a precipitate was noted in very shallow water, especially in the lagoon at Marquesas. A precipitate was coming down in the water and a calcareous crust was forming on the blades of eel-grass.

DEPARTMENT OF MERIDIAN ASTROMETRY.*

BENJAMIN BOSS, DIRECTOR.

A glance at the reports of the Department of Meridian Astrometry would seem to indicate that special investigations form the bulk of the activities of the Department, because of the amount of space devoted to these investigations in the reports as compared with that devoted to outlining the observational and computational work upon the general catalogue. This, however, is not the case. Such a great undertaking as we have in hand can only proceed by stages, for reasons of economy. These operations, though absolutely essential to the final results, present few elements of special interest to the general scientific public and therefore are barely referred to in the reports, though each operation may occupy the time of a number of computers for months. In this respect our work differs largely from that of many other scientific organizations wherein the investigations call for a comparatively short effort, so that many investigations are completed within a brief time.

The manner in which our reduction of observations is conducted is also responsible for our inability to supply, in advance, data required by other observatories. To make special reductions to supply data for a few individual star places would double the cost of reduction for these stars and the advance star places would be less accurate than the finally deduced places.

The San Luis observations will very shortly be in such shape that they can be prepared for the printer. It is a matter deserving of careful consideration whether these results should be published as a separate catalogue. In one sense of the word the southern observations form a completed task, but they will eventually be combined with the northern observations to form a continuous catalogue from pole to pole. In the process of combination the observed positions will be altered by such amounts as are found necessary to bring southern and northern star positions into agreement, and for a zone extending from the zenith at Albany to the zenith at San Luis the positions of fundamental stars will be formed by a combination of northern and southern observations. For such stars it would be possible to print the positions of the separate catalogues in special columns. On the other hand, by printing the catalogues separately the San Luis observations would become available in advance of the northern observations, and by the subsequent publication of tables of correction, the position of each catalogue could be readily deduced with a small amount of labor.

The collection of the observations upon the catalogue cards is begun.

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STELLAR DISTRIBUTION.

The confirmation given to the probable existence of a secondary plane of distribution of the brighter stars, by the apparent existence of a secondary and very similar plane of distribution of the apices of the real motions of the stars, has led the Director to a more thorough investigation of the subject, both through a discussion of the distribution of the stars and an examination of their proper-motions. In most statistical methods there has been a tendency to force the results into a state of symmetry with respect to the Galaxy. The present investigation endeavors to treat the motions and distribution of the stars by taking cognizance of possible irregularities in these elements in different parts of the sky. It is realized that far more material is needed for an exhaustive treatment of the subject, but a few salient features may be detected even with our limited material.

According to the method adopted for the treatment of distribution of the stars to the $6^{M}.0$, the pole of the secondary distribution was placed at R. A. = 160°, Decl. = − 35°. Including stars to the $6^{M}.5$, the pole was shifted to R. A. = 194°, Decl. = − 24°. For stars to the $6^{M}.5$ inclusive, the pole of the plane of avoidance is at R. A. = 164°, Decl. = + 73°. The large inclination of the plane of secondary distribution with respect to the Galaxy was unexpected, and it was even less expected to find the plane of avoidance nearly at right angles to the plane of secondary distribution. When coupled with the phenomenon of a secondary plane for the distribution of the apices of the real motions of the stars it is natural to wonder whether we are not possibly dealing with two systems of stars—one very definite, with the Galaxy as its principal plane, the other less definite and considerably inclined to the Galaxy.

An interesting feature of the investigation is to find the sun's apex accurately located in the plane of the secondary distribution.

Certain peculiarities are manifested in the distribution of the stars in accordance with type. In galactic latitude 0° there is a distinct progression in galactic longitude on the part of the maxima of distribution of the various types from B to K. In latitudes −20° and −40° the points of maximum distribution for type K correspond to minimum distribution for type A.

Further work on this investigation is in progress.

COLLIMATION OF THE OLCOTT MERIDIAN CIRCLE.

Mr. Roy has continued his investigation of the apparent lost motion in the collimation of the meridian-circle instrument. In addition to the collimations of the regular observing program he determined 71 under such conditions as to confirm or refute the probability of a lag.

The hypothesis of lost motion assumes that the collimation is invariable as long as the temperature fluctuates within the amount of the

lost motion. As soon as the temperature rises or falls beyond a certain point a new maximum or minimum is established. The observed data seem to confirm the existence of such a term.

The former practice was to group the collimations over a period within which the temperature coefficient seems to satisfy the collimations. The advantages in using the lag term consist of the longer range over which the collimation can be applied by formula and the saving of labor by applying a term which is constant for several weeks.

THE VARIATIONS IN SPECTRAL TYPE OF THE FOURTH CLASS VARIABLE STAR l CARINÆ.

A paper was prepared and read at the twenty-first meeting of the American Astronomical Society at Albany by Dr. Albrecht on the variations in spectral type of the fourth class variable star *l Carinæ*, of which a brief abstract follows.

When the discovery was made in 1906 that many of the lines in stellar spectra show slightly different wave-lengths in the different stellar types and that these differences progress with the regular type sequence, it was pointed out that similar changes in wave-length which would be progressive with the phase of light-variation might be found in the spectra of individual variable stars. Such periodic changes in wave-length, if found, would offer a quantitative method for the determination of actual changes in spectral type synchronously with the changes in light. The limited amount of material then available, principally for the star *η Aquilæ*, "showed very strong indications of just such variations in the positions of certain lines." At Dr. Albrecht's suggestion, Director Campbell, of the Lick Observatory, asked Dr. Heber D. Curtis, then in charge of the D. O. Mills Observatory in Chile, to secure for this study series of spectrograms of the fourth-class variable stars *l Carinæ* and *κ Pavonis*. The present paper discusses the measures of the spectrograms of *l Carinæ* which were secured at that time. The methods employed are described in the *Astrophysical Journal*, vol. 33, p. 130, 1911. The details of the investigation will be published later. Briefly summarizing, it may be stated that, as in the case of *η Aquilæ* so also for *l Carinæ*, variations in spectral type are shown to occur. For this star the range of variation is seven-tenths of a type interval, the type being F 7.8 near light maximum, G 2.9 at a phase intermediate between maximum and minimum, and G 4.8 near light minimum.

PERSONAL EQUATION OF SAN LUIS OBSERVERS.

The tabulation of the residuals of the San Luis transits shows decided systematic differences between the results obtained by the different observers dependent upon declination. Mr. Varnum has drawn up the results and discussed them. The mean from the three fundamental observers was taken as a standard and the error of each observer rela-

tive to this mean was determined. This necessitated several approximations in order that the mean correction to P. G. C. for each star might be fairly free from the effect due to unequal observation by each of the three fundamental observers. The second approximation appeared to have corrected the mean for this effect, so the third approximation was considered definitive. Curves were drawn to represent the residuals. The corrections for relative personal error, when applied to each series, harmonized them and reduced the probable error of a single observation to $\pm 0^{s}.0236 \sec \delta$.

The following table shows the residuals for each observer clamp east and the adopted values as derived from the curves:

R. H. T. Cl. East.					Roy. Cl. East.					W. B. V. Cl. East.				
Decl.	No. of Obs.	Obs'd.	Curve.	O—C	Decl.	No. of Obs.	Obs'd.	Curve.	O—C	Decl.	No. of Obs.	Obs'd.	Curve.	O—C
-65.3 SP	77	-.007	-.006	-001	-65.5 SP	32	+.018	+.016	+002	-65.6 SP	52	-.025	-.025	000
-68.0	56	-.014	-.016	+ 2	-68.0	51	+.009	+.014	- 5	-68.1	67	-.026	-.025	- 1
-70.7	40	-.018	-.016	- 2	-71.2	43	+.026	+.021	+ 5	-71.2	48	-.029	-.031	+ 2
-74.0	27	-.003	-.005	+ 2	-74.5	29	+.008	+.009	- 1	-74.4	23	-.037	-.034	- 3
-77.8	56	-.008	-.007	- 1	-77.6	53	+.008	+.009	- 1	-78.0	45	-.007	-.007	0
-80.0	48	-.006	-.004	- 2	-79.9	42	+.007	+.009	- 2	-80.2	44	-.011	-.010	- 1
-83.2	48	-.008	-.006	- 2	-83.2	51	+.003	+.002	+ 1	-83.3	32	-.006	-.005	- 1
-86.0	62	-.006	-.008	+ 2	-86.0	50	-.001	-.001	0	-86.1	37	+.003	+.004	- 1
-88.5 SP	33	-.009	-.006	- 3	-88.7 SP	19	+.008	+.005	+ 3	-88.8 SP	19	+.003	+.002	+ 1
-88.3	51	-.011	-.011	0	-88.2	32	-.010	+.005	- 15	-88.5	29	+.005	+.005	0
-85.4	66	-.002	-.002	0	-85.8	52	+.007	+.008	- 1	-85.7	44	+.001	+.002	- 1
-82.8	67	+.002	.000	+ 2	-83.0	61	+.008	+.008	0	-83.1	45	+.001	+.001	0
-79.7	82	-.001	-.002	+ 1	-79.7	70	+.015	+.015	0	-79.7	64	-.002	-.005	+ 3
-77.2	72	-.003	-.003	0	-77.3	47	+.012	+.010	+ 2	-77.1	46	-.010	-.005	- 5
-74.0	43	-.004	-.004	0	-74.0	33	+.012	+.015	- 3	-73.6	42	-.012	-.014	+ 2
-70.7	59	+.002	+.002	0	-70.5	69	+.017	+.017	0	-70.6	66	-.017	-.018	+ 1
-67.7	95	+.005	+.006	- 1	-67.6	88	+.019	+.018	+ 1	-67.6	81	-.022	-.023	+ 1
-65.1	88	+.008	+.006	+ 2	-65.0	75	+.019	+.020	- 1	-64.7	85	-.017	-.018	+ 1
-61.7	50	+.005	+.003	+ 2	-61.7	52	+.022	+.023	- 1	-61.9	65	-.017	-.017	0
-58.8	64	+.007	+.009	- 2	-58.7	48	+.023	+.021	+ 2	-58.7	48	-.023	-.023	0
-55.8	55	+.002	+.001	+ 1	-55.8	43	+.028	+.030	- 2	-55.7	44	-.020	-.020	0
-52.5	52	+.001	+.001	0	-52.7	47	+.030	+.031	- 1	-52.7	47	-.018	-.016	- 2
-49.6	54	+.003	+.004	- 1	-49.7	39	+.019	+.020	- 1	-49.9	48	-.024	-.024	0
-47.0	54	+.001	+.004	- 3	-46.8	39	+.038	+.035	+ 3	-46.9	46	-.029	-.031	+ 2
-43.6	78	+.019	+.019	0	-43.6	65	+.020	+.023	- 3	-43.5	66	-.032	-.032	0
-40.5	107	+.017	+.015	+ 2	-40.6	95	+.021	+.022	- 1	-40.4	108	-.034	-.032	- 2
-37.8	167	+.007	+.007	0	-37.6	147	+.021	+.020	+ 1	-37.7	127	-.038	-.038	0
-34.7	130	+.002	+.002	0	-34.7	127	+.015	+.017	- 2	-34.8	127	-.030	-.030	0
-31.9	92	+.003	+.004	- 1	-32.0	90	+.014	+.014	0	-32.1	83	-.008	-.011	+ 3
-28.9	127	-.001	.000	- 1	-28.8	130	+.005	+.004	+ 1	-28.9	91	+.001	+.001	0
-25.8	129	-.003	-.003	0	-25.8	92	-.001	-.002	+ 1	-25.7	88	+.003	+.004	- 1
-22.9	153	-.006	-.006	0	-22.9	111	+.005	+.004	+ 1	-23.0	111	-.003	-.002	- 1
-20.0	74	-.002	-.002	0	-19.8	82	-.007	-.006	- 1	-20.1	50	+.006	+.004	+ 2
-16.5	105	+.001	+.001	0	-16.5	96	-.003	-.003	0	-16.5	91	-.002	-.002	0
-13.9	66	.000	+.001	- 1	-13.8	48	-.003	-.001	- 2	-13.7	46	+.006	+.005	+ 1
-10.3	87	-.001	-.001	0	-10.7	82	-.001	-.001	0	-10.2	80	.000	+.001	- 1
- 8.2	106	-.007	-.006	- 1	- 8.2	78	+.001	+.002	- 1	- 8.2	81	+.001	-.001	+ 2
- 4.8	99	-.003	-.004	+ 1	- 4.6	98	+.001	+.002	- 1	- 4.7	66	-.001	-.001	0
- 1.4	94	-.001	-.001	0	- 1.7	66	-.007	-.006	- 1	- 1.7	82	-.003	-.001	- 2
+ 1.1	71	-.008	-.008	0	+ 1.3	69	-.002	-.003	+ 1	+ 1.3	47	+.003	+.002	+ 1
+ 4.2	118	-.008	-.008	0	+ 4.2	86	-.009	-.009	0	+ 4.2	91	-.001	-.001	0
+ 7.1	144	-.006	-.007	+ 1	+ 7.0	89	-.006	-.006	0	+ 7.1	114	+.004	+.006	- 2
+10.3	127	-.004	-.003	- 1	+10.1	113	-.003	-.003	0	+10.1	110	.000	.000	0
+13.2	85	-.005	-.005	0	+13.2	81	+.001	+.002	- 1	+13.2	79	-.001	-.005	+ 4
+15.7	96	-.006	-.003	- 3	+15.9	65	+.005	+.003	+ 2	+15.7	77	-.006	-.004	- 2
+19.3	82	-.005	-.005	0	+19.2	64	.000	.000	0	+19.4	72	.000	+.001	- 1
+21.8	106	-.002	-.003	+ 1	+22.1	87	-.002	-.001	- 1	+21.9	78	-.003	-.005	+ 2
+24.9	84	+.001	+.003	- 2	+24.9	69	.000	-.001	+ 1	+24.7	62	-.005	-.005	0
+28.1	96	-.007	-.007	0	+28.0	101	.000	+.002	- 2	+28.0	78	-.010	-.010	0
+31.2	35	+.015	+.013	+ 2	+31.2	24	-.004	-.004	0	+31.2	29	-.018	-.016	- 2
+33.8	30	+.006	+.009	- 3	+33.9	17	-.002	-.006	+ 4	+33.9	29	-.012	-.013	+ 1
+37.7	42	+.016	+.020	- 4	+37.8	31	-.006	-.005	- 1	+37.9	27	-.002	-.005	+ 3
+39.9	69	+.018	+.015	+ 3	+40.2	44	.000	-.001	+ 1	+39.8	35	-.022	-.021	- 1
+43.0	41	+.020	+.021	- 1	+42.8	35	-.015	-.015	0	+43.0	37	-.026	-.026	0
+46.2	32	+.020	+.022	- 2	+46.0	24	-.028	-.028	0	+46.1	31	-.010	-.011	+ 1
+48.8	23	-.009	-.001	- 8	+48.7	20	-.007	-.009	+ 2	+48.8	23	-.036	-.029	- 7

The results for Clamp West are just as systematic as those for Clamp East, but are omitted for the sake of brevity.

FURTHER INVESTIGATIONS DEPENDENT UPON PARALLAX.

In *Astronomical Journal* No. 707 Dr. von Flotow[1] has shown the existence of two velocity-planes. As systematic errors of observed parallaxes and radial velocities have not yet been carefully discussed, additional material will not lend much strength to the discussion. He therefore considered it best to further develop the parallax problem in its relation to the two velocity-planes, illustrating the methods by means of the 116 stars.

Not knowing the physical characteristics of the two planes, there is no criterion, in ambiguous cases, to decide in which plane the apex belongs; but studying the computed corrections of parallaxes as they are given by $(\delta\pi)_0$ and its variation $(\delta\pi)_1$, it is possible, in a few cases, to decide whether a given stellar apex belongs to Plane I, to Plane II, or has to be rejected. In this way he obtained a slight alteration of the two groups.

Group I. Rejected 1, added 1
Group II. Rejected 1, added 3

A solution of the corrected groups leads to the following corrected coordinates of the two planes:

Plane I (32 apices)	$\gamma_1 = 192^{\circ}.80 \pm 3^{\circ}.48$	$\kappa_1 = +32^{\circ}.55 \pm 2^{\circ}.31$
Plane II (31 apices)	$\gamma_2 = 146.34 \pm 5.84$	$\kappa_2 = -48.89 \pm 3.87$

These values showing little tendency toward better agreement of the mean errors or of the condition of perpendicularity as given by

$$\tan \kappa_1 + \cot \kappa_2 \cos (\gamma_2 - \gamma_1) = +0.0371$$

are taken as a basis for further investigation.

Newcomb's analytical treatment of three perpendicular principal planes, given in his "Contributions to Stellar Statistics" (Carnegie Inst. Wash. Pub. No. 10), suggests the hypothesis of a third plane perpendicular to the two given above. Consideration of this hypothesis shows the following distribution of the apices of 89 stars, which may be classified as belonging to one of the three planes:

Plane I—46 p. ct. Plane II—46 p. ct. Plane III—8 p. ct.

The given data show little evidence of the existence of a third perpendicular plane.

Considering all the elements entering in the parallax problem, two are vital and direct further investigation: (1) the influence of the assumed solar motion; (2) the influence of the partial differential coefficients of the position angle.

The derivation of the coordinates of the two planes given above was founded on L. Boss's solar apex $A = 270^{\circ}.5$, $D = +34^{\circ}.3$, and on a value

[1] A member of the observatory staff from January 25, 1915, to May 1917.

of 20 kilometers for the solar velocity. The material was revised, assuming the following rectangular coordinates of solar motion:

$$x = -2.3\text{ km.} \qquad y = -13.2\text{ km.} \qquad z = +14.9\text{ km.}$$

corresponding to a solar apex A=260°.1, D=+48°.0, and to a solar velocity of 20.04 km. The reason for this choice appears later. As a result of the new elements of solar motion the distribution of stellar apices changes as follows:

Group I. Rejected 4, added 2 Group II. Rejected 6, added 6

with a material correction

$$d\pi = 0''.057 + 0.005 d\rho'$$

and a maximum value for $d\pi$ of 0''.082.

Solving the conditional equations of the two groups based on the new solar motion, we obtain the following coordinates of the two planes:

Plane I (30 apices) $\gamma_1 = 189°.47 \pm 3°.98$ $\kappa_1 = +34°.84 \pm 2°.62$

Plane II (31 apices) $\gamma_2 = 144.63 \pm 6.51$ $\kappa_2 = -50.04 \pm 4.06$

Comparing these results with those first given above leads to the important conclusion that the two solutions agree within a few degrees. The mean errors are of the same order and the deviation from perpendicularity is slight (−0.0125).

The second important point concerns the position angle. This angle is independent of the radial velocity. Moreover, the partial derivatives with respect to the other elements are very simple. These important facts lead to a determination of the distances for all apices certainly belonging to the velocity planes found above. The further investigations may be discussed in two ways: (1) using the observed radial velocities we are able to determine the corresponding solar motion. A preliminary computation results in the second value of solar motion used above. It is interesting to see that this result is in good agreement with the position of the solar apex derived by L. Boss from G-type stars, although this type is not predominant in the star material here treated, as may be seen from the accompanying table of distribution of types in the two groups. Then (2), using a given solar motion, we are able to compute the resulting radial velocities and to compare them with the observations. In this way we may obtain some insight into solar parallax and the principle of relativity, if we study the measured displacements of spectral lines.

	I	II
	%	%
Type A...	19	7
Type F...	28	28
Type G...	25	34
Type K...	28	31

In these and similar investigations, where we have to deal only with the possible influence of variations with respect to the principal elements, the results obtained are always a function of the assumed weights and we have to pay special attention to this delicate subject.

OBSERVATIONS.

During the year, 10,651 observations were taken on 89 nights, with 513 supplementary observations taken on 52 days for clock error, clock rate, and independent azimuth. The observations were distributed among the observers as follows: S. Albrecht, 4,674; Arthur J. Roy, 5,023; W. B. Varnum, 954. The circle-readings for zenith distance showed the following distribution: S. B. Grant, 2,792; H. Jenkins, 4,390; H. Raymond, 3,331. In respect to the four positions of the instrument these observations were distributed: AE 558, AW 799, BE 5,306, BW 3,988. But for the unusual lack of clear weather the present observing program would have been finished. There remain less than 800 stars which have not the full quota of observations, and of these about 90 require 2 observations. Of the fundamental stars, only 61 lack more than 2 observations.

REDUCTIONS.

All classes of reductions as enumerated in the last report have been brought more nearly up to date. Considerable progress has also been made with the General Catalogue.

THE ZONE CATALOGUES OF 1900.

The final proof of the Albany Zone Catalogue for 1900 has been corrected and is in the hands of the printer; it will soon appear as publication No. 246 of the Carnegie Institution of Washington.

STAFF.

The activities of the staff have not changed materially since the last report. A few changes in personnel may be mentioned. Dr. A. von Flotow and Miss Florence L. Gale resigned. Dr. Roscoe F. Sanford, Mr. Carl L. Stearns, and Miss Marie Lange have joined the staff.

MOUNT WILSON SOLAR OBSERVATORY.*

George E. Hale, Director.

INTRODUCTORY SKETCH OF THE YEAR'S WORK.

The far-reaching influences of the war, so disastrous in their effect upon the progress of science in Europe, are clearly reflected in the Observatory's history for the past year. The resulting diminution in research activity, however, has not been serious. The Director has been called upon to devote nearly all of his time to the organization and work of the National Research Council, which since February has served as the Department of Science and Research of the Council of National Defense. Fortunately he was able to leave the Observatory's work in the hands of the Assistant Director, who deserves full credit for its successful conduct during the greater part of the year.

The prolonged activity of the sun, hardly yet at its maximum, has afforded excellent opportunity for a variety of work. Sun-spots are so numerous that an average of nearly 40 (including the members of groups) have been observed daily for magnetic phenomena, while other evidences of solar unrest have been on a corresponding scale. The successful continuation of laboratory researches on the Stark effect has provided means for another test of the presence of free electricity in sun-spots, but the outcome, as in previous years, has been negative. Thus, while we can hardly doubt that the intense magnetic fields in sun-spots are due to electrically charged particles whirling in vortices, the full explanation of the effect is yet to be developed. The same may be said of the nature of the spot vortex. The association in pairs of sun-spots of opposite magnetic polarity remains a phenomenon of almost unbroken occurrence and undoubted significance. But the simple hypothesis that the two members (single or multiple) of the group represent the extremities of a half-ring vortex, while fruitful as a guide to research, can hardly be taken at its face value, in view of the complex polarity phenomena presented by large and active spot-groups; so long as this hypothesis remains useful in suggesting new lines of work, however, it will not be wholly discarded.

The sudden reversal of magnetic polarity exhibited by sun-spots at the last minimum of solar activity (1912) has given no sign of repetition since that date. If the maximum is to be accompanied by a reversion to the former state, the effect should soon appear. Meanwhile we may speculate sparingly on the meaning of this unexpected change of polarity. If, as we suppose, the magnetic fields in spots are due to the whirl of charged particles in vortices, the direction of the rotary

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motion in the preceding (and following) spots of bipolar groups is now opposite to its direction during the years 1908 to 1912. Thus it is as if the cyclones and tornadoes north of the earth's equator were suddenly to whirl clockwise instead of counter-clockwise—an event impossible without profound changes in atmospheric circulation.

In the sun, as the last report pointed out, the rotary motion of the hydrogen vortices of the upper atmosphere showed no reversal of sign at the sun-spot minimum. This stability presumably indicates that their direction of whirl is determined, not by the action of the magnetic fields below them, but mainly by the conditions existing in the higher atmosphere, where marked variations in solar activity have been shown to be unaccompanied by fundamental changes in the rotation law. Within the photosphere, however, a very different condition of things must exist. In fact, the reversal of spot polarity provides a possible clue to the cause of the sun-spot cycle, strongly suggesting, to say the least, that its seat is within the sun, in spite of all attempts to explain the cycle as a result of the influence of planetary or other external phenomena.

The inclination of the solar magnetic axis, now definitely shown to make an angle of about 6° with the sun's axis of rotation, will provide food for thought to students of the earth's magnetism. Two bodies, the earth and the sun, rotating in the same direction, are now known to be magnets of the same polarity, with magnetic axes which fail to coincide with their rotation axes. The analogy, it may be hoped, will serve as a useful guide to the theoretical studies of magneticians.

The successful investigator must devote much of his attention to the elimination of sources of error and the critical investigation of plausible hypotheses, even though the latter may prove in the end to be false guides. The relativity hypothesis indicates that the lines of the solar spectrum should be shifted very appreciably toward the red when compared with the corresponding lines in terrestrial sources. The test is rendered extremely difficult by the conditions existing in terrestrial light-sources, which produce peculiar and variable shifts of the lines that must be used as standards; but through persistent and painstaking work these difficulties have been overcome, thus furnishing reliable standards of comparison and supplying a negative answer to the relativity criterion. The uncertainties experienced in measuring the members of closely adjacent pairs have also been reduced, and the displacing effect of scattered light has been shown to be negligible under the conditions existing on Mount Wilson. Thus the way has been prepared for the study and elucidation of the most minute shifts of solar lines.

While solar research still retains its prominent place in the work of the Observatory, the development of stellar and nebular investigations continues to increase. The direct photography of nebulæ has not only recorded new and interesting details of structure, but has also

revealed the prevalence in these objects of faint temporary stars, whose tendency to form in the branches of spiral nebulæ strongly suggests an important analogy with the well-known fact that bright temporary stars invariably blaze out in or near the Milky Way. The classic problem of "island universes" is again under vigorous discussion, and much attention will be paid here to its further investigation.

The distances of the stars, so fundamental a factor in all astronomical studies, whether structural or physical, are now determined by two methods. The first involves the simple trigonometrical principle of measuring the displacement of a star's position, as observed from opposite extremities of the earth's orbit. From this accurately known base-line their distances are readily calculated, precisely as in terrestrial triangulations. The high precision of differential measurements obtainable with such an instrument as our 60-inch reflector would seem to make this method very reliable. Insidious systematic errors, however, may enter to vitiate the conclusions. It is therefore satisfactory to find, as the result of careful study, that these are apparently very small.

The use of the second method, recently devised here and described in the last annual report, has led to extensive and highly significant developments. By this method every good photograph of a star's spectrum yields a measure of its distance, given by a simple determination of the relative intensities of certain lines. The limitation of application to the more advanced types of spectra has been partially removed by the inclusion of new groups of lines, which serve as criteria in the earlier types. Moreover, any doubts that may have existed as to the accuracy of the method have been dispelled by a comparison of the spectroscopic and trigonometric parallaxes of 360 stars, which shows an exceedingly satisfactory agreement. The rapidity and simplicity of the method will therefore at once lead to extensive applications.

The first of these, involving an investigation of the relationship between the absolute magnitudes and motions of some 1,300 stars, clearly indicates an increase of velocity with decrease in absolute magnitude, independent of distance from the sun. The conclusion that the intrinsically fainter stars move more rapidly than the brighter ones must prove of exceptional significance in the theory of stellar evolution. Another interesting conclusion, in harmony with previous results for stars of earlier types, is the marked condensation of the later-type stars of high luminosity in the plane of the Milky Way.

The extensive task of determining the photographic magnitudes of stars in 115 of the Selected Areas of Kapteyn has been essentially completed, and work on the photovisual magnitudes is also advancing. The former results have afforded means for a study of the increase in the number of the stars toward the plane of the Milky Way. From

counts of 40,000 stars, a reliable measure of the relation between stellar density and galactic latitude has been deduced which is in harmony with Professor Kapteyn's conclusion that the faint stars show a high galactic condensation. This result is further confirmed by a discussion of Professor Turner's counts of some 600,000 stars in the Astrographic Catalogue. Stars of photographic magnitude 17.5 are from twenty to thirty times as numerous in the plane of the Milky Way as at its poles.

The continuation of a comprehensive investigation of globular star clusters has yielded new and interesting results. Thus it appears to be possible to estimate the relative distances of clusters containing typical short-period variable stars, since the median magnitudes of these objects are constant for each cluster, while varying from one system to another. The method, if substantiated by further work, will be of great value, in view of the extreme remoteness of these objects, which places them beyond the reach of other means of measuring distances.

Another outcome of this investigation is the discovery that the distribution of the fainter stars in certain globular clusters reveals an apparently characteristic elliptical form. In Messier 13, for example, there is an axis of elongation along which the stars are 30 per cent more numerous than along the minor axis. As this result is supported by other phenomena, it may prove that the so-called globular clusters are actually more or less flattened spheroids, analogous to our own galactic system. Additional work on clusters shows no evidence of effectual scattering of light in space and indicates provisionally that the depth of the Milky Way in some directions may exceed 25,000 light-years.

The Observatory's policy of devoting special attention to laboratory investigations for the interpretation of solar and stellar phenomena has been continued with the aid of improved facilities. The electric furnace has been used for the study of anomalous dispersion phenomena and for the investigation of the effect of changes in temperature, vapor density, and surrounding atmosphere on the spectra of iron, calcium, strontium, and barium. The very diffuse arc lines of barium are sharp and of modified structure in the furnace, where a triplet or doublet sometimes appears in the place of the single arc line. Measurements of the sharp furnace lines indicate their apparent agreement with faint unidentified lines of the solar spectrum, where their structure corresponds with that given by the furnace. The series lines of calcium, produced by the impact of cathode rays, show marked differences of intensity as compared with their appearance in other sources.

The further study of the effect of an electric field on radiation, which has now been extended to include the spectra of iron, chromium, nickel, titanium, and manganese, has shown no appreciable effect for the great majority of lines; 74 lines of chromium, 8 of iron, and about

12 of nickel, however, exhibit either displacement or decomposition in an intense electric field. It is interesting to find that under these conditions the relative intensity of the lines is unlike that given by the arc, spark, or furnace.

The important task of determining the wave-lengths of lines serving as primary and secondary standards has already been mentioned. This has now reached a point where many of the unstable lines of iron can be safely used, providing that suitable precautions be taken in the adjustment of the electric arc. In this connection the displacing effect of the spark on lines of iron has been determined and the pressure shifts of iron lines have been remeasured, with improved apparatus, to eliminate pole effect.

The chief work of construction has included the enlargement of the Pasadena physical laboratory to nearly double its former area; the erection of a two-story concrete dormitory on Mount Wilson, adjoining the Monastery, to provide for the increased staff required for the 100-inch telescope; and the essential completion of the dome and mounting for this instrument. The erection on Mount Wilson of a 75-foot steel flagpole, flying a large American flag, for both of which we are indebted to Mr. Edward D. Adams, should also be recorded here as an appropriate event of the year.

As the Director has had so small a part in the year's activities, he may be permitted to express his pleasure in the important advances made in every department of the Observatory's work and his high appreciation of the faithful and devoted services of every member of the staff. It is well to remember that all forms of scientific research represent a very real service to the state. Astronomy is not so remote from the practical affairs of life as a superficial estimate might conceive it. Poincaré has shown this most clearly in his book on *The Value of Science*, where he asks how far advanced the world's civilization would be if the stars had always been hidden by clouds. It is interesting to observe that in demonstrating the part played by astronomy in the world's progress he does not even mention such important matters as navigation and the determination of time, because of their insignificance as compared with far more impressive contributions. Thanks to observatories in all quarters of the earth, the picture of the universe still continues to unfold and to influence progress in every field of thought. We are happily in a period of unprecedented progress, when the empirical conceptions of an earlier time are rapidly giving place to well-grounded views. The privilege of aiding in this advance, at a time when the pioneer stage has not yet been passed, will be appreciated by those who reflect on the true meaning and influence of astronomical discovery.

STAFF.

Such time as the Director could give to astronomy during the year has been mainly devoted to solar investigations, continued in collaboration with several members of the staff. Dr. Walter S. Adams, Assistant Director, has pushed forward his investigations in stellar spectroscopy and has had general charge of the Observatory during the Director's absence. Professor Frederick H. Seares, superintendent of the Computing Division and editor of the Observatory publications, has continued his researches in stellar photometry, the determination of the position of the sun's magnetic axis, and other subjects. Dr. Arthur S. King, superintendent of the Physical Laboratory, has carried on various investigations with the electric furnace. Dr. Charles E. St. John has given most of his attention to the determination of the fundamental wave-lengths of solar and standard lines, with special reference to a possible relativity effect. Professor G. W. Ritchey has remained in charge of the work of the optical shop and has continued the photography of nebulæ with the 60-inch reflector. Dr. J. A. Anderson has devoted most of his time to the study of the Stark effect. Mr. Harold D. Babcock has continued his investigations on standards of wave-length and related subjects. Mr. Ferdinand Ellerman has given much of his time to solar observations and has served as Observatory photographer. Mr. Francis G. Pease, in charge of instrument design, has given special attention to the 100-inch telescope, besides continuing his photographic work on nebulæ and star clusters. Dr. Harlow Shapley has advanced his investigations of star clusters, variable stars, and stellar photometry. Dr. Adriaan van Maanen has continued his determinations of stellar parallaxes and the measurement of spectra to fix the position of the sun's magnetic axis. Dr. Seth B. Nicholson has given most of his attention to solar observations and has calculated the orbit of the ninth satellite of Jupiter. Professor Alfred Joy, who has been engaged in stellar spectroscopic work, has also taken part in the solar observations. Dr. Gustav Strömberg has devoted himself to the study of the stellar spectroscopic results. Mr. Ray Campbell assisted in the solar observations until May, when he resigned his position. His work was continued by Dr. Walter T. Whitney from that time until the end of August, when Mr. Arthur S. Dockham joined the staff to assist in these investigations.

Professor J. C. Kapteyn, for ten years Research Associate of the Institution, has not been able to visit Mount Wilson since early in the war. He is actively continuing his work in Groningen, however, and we are providing material for some of his investigations.

The members of the Computing Division have assisted in the work of the various departments as follows: Miss Ware and Miss Miller have been engaged with the solar investigations carried on by Dr. St. John. Miss Burwell, Miss Stone, Miss Shumway, and, for a part of the time,

Miss Brayton, have made measures and reductions relating to stellar spectroscopy. Miss Richmond, Miss Joyner, Miss Carolyn Burns, Miss Winn, and Miss Davis have been occupied with stellar photometry, and Miss Richmond has assisted Mr. Pease and Dr. Shapley with the discussion of an extensive series of counts on photographs of clusters. For part of the year Miss Davis was also occupied with reductions of parallax measures for Dr. van Maanen. Miss Wolfe has given her time to reductions of stellar parallax and the sun's general magnetic field. She has also done miscellaneous computing and photographic work, and has assisted in the library. Miss Margherita Burns and, for the latter part of the year, Miss Brayton, have been engaged with the work of the Physical Laboratory. Miss Connor has continued as librarian and has assisted with the editorial work.

Dr. J. van der Bilt served as a volunteer assistant on Mount Wilson from September to January. Mrs. Harlow Shapley has continued her service as a volunteer assistant in connection with the work in stellar photometry. Miss Edna Carter, Associate Professor of Physics at Vassar College, who began work last year as a volunteer assistant in the physical laboratory, is still devoting her attention to metallic spectra produced by the cathode discharge. Mr. Hugo Benioff has served for two months as volunteer assistant on Mount Wilson.

Mr. L. B. Aldrich has continued the work of the Smithsonian Astrophysical Observatory on Mount Wilson during the summer of 1917.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

Few changes have been made during the year in the equipment for solar observations. The final details in the remodeling of the Snow telescope and the installation of the new vertical spectrograph have been delayed by the pressure of other work in the instrument shop, but it is hoped that these important improvements may soon be completed.

A small but valuable addition to the 75-foot spectrograph consists of a parallel-plate micrometer, mounted in the plate-holder support, and serving for daily visual measures of the strength of the magnetic fields in sun-spots.

SOLAR PHOTOGRAPHY.

During the year ending August 31, 1917, the following photographs were taken with the 60-foot tower telescope by Messrs. Ellerman, Nicholson, Joy, van der Bilt, Campbell, Whitney, and Benioff: photoheliograms of 6.5-inch image, 307 on 307 days; 5-foot spectroheliograms ($H\alpha$, entire 6.5-inch disk), 298 on 298 days; 13-foot spectroheliograms (K and $H\alpha$, 2-inch disk and prominences; $H\alpha$, portions of 6.5-inch disk), 1,248.

Photographs of spectra made with the 75-foot spectrograph of the 150-foot tower telescope include 124 of the disk for the sun's general field, 80 of sun-spots, and 15 for miscellaneous purposes.

Beginning May 20 and ending September 28, 1916, the sun was photographed on 132 consecutive days.

During the summer of 1917 there was much partial cloudiness; for over five weeks some clouds formed every day.

STEREOGRAMS OF CALCIUM AND HYDROGEN FLOCCULI.

The interesting results obtained last year by combining $H\alpha$ images of the disk for stereoscopic study have been extended, with special reference to the elimination of false effects of relief frequently encountered in such work. If two photographs of distant mountains, taken from the extremities of a long base-line, are wrongly combined for stereoscopic vision (left for right), the eyes easily see the lower mountains in the foreground as a deep cave, but reverse the peaks with great difficulty. The tendency to persist in seeing such forms in their normal relief doubtless explains the impossibility of reversing certain stereograms of $H\alpha$ flocculi near the limb, where the time interval which separates the two photographs is more than sufficient to give true stereoscopic vision.

It is obvious, however, that the surest results and the best sense of relief will be obtained by combining images well separated in time, provided that the changes in form of the flocculi and prominences during the interval are not too serious. An admirable appearance of sphericity of the solar image and high relief of the prominences on the disk results from the stereoscopic combination of two $H\alpha$ photographs of small diameter, separated by an interval of 3 hours. Any false effects caused in certain prominences by changes in form can be detected by the use of various pairs of photographs made at different times.

The value of this method is obvious, especially in the study of prominences on the solar disk. No one can doubt their character when seen in this way, or make the mistake of attributing the dark flocculi on $H\alpha$ images to other causes.

MAP OF THE SUN-SPOT SPECTRUM.

As stated in the last annual report, our new map of the sun-spot spectrum, on a scale of 1 cm. to the angstrom, was completed last year by Mr. Ellerman for the region λ 6000 to λ 6450. During the winter enlargements were made from additional negatives for the region λ 5400 to λ 6000, and new negatives have now been obtained which will permit the entire region from λ 3800 to λ 6600 to be included in the map.

INCLINATION OF THE LINES OF FORCE IN SUN-SPOTS.

In the last report reference was made to the differences in the polarization of Zeeman triplets observed in various parts of a spot near the sun's limb. These correspond with what would be expected on the assumption that the lines of force at the center of the spot are nearly parallel to a solar radius, and that the angle they make with the surface decreases in going outward to the edge of the penumbra. In the case of small spots very close to the limb it is difficult to see the lines of force (directed toward the observer) on the edge of the penumbra lying nearest the center of the sun, but in large spots this difficulty is not experienced. It goes without saying that a single symmetrical spot is needed to bring out the effect properly, for if companions are present the lines of force are distorted, with corresponding changes in the polarization phenomena.

If a single symmetrical spot is watched as it crosses the sun's disk, the changes in the polarization phenomena are generally such as would be expected from the above characteristics of the lines of force. When the spot is near the center of the disk, plane polarization is best seen near the edges of the penumbra, where the lines of force are nearly normal to the line of sight. It sometimes happens, however, that the central component of triplets remains visible in spots near the center of the sun, where its intensity would be very small if the lines of force were really radial. Very interesting polarization phenomena are observed in complex sun-spots, especially in regions between closely adjacent spots of opposite polarity.

SUN-SPOT POLARITIES.

Sun-spots have been so numerous that the magnetic polarities of nearly 40, on an average, have been observed each day with the 75-foot spectrograph of the 150-foot tower telescope. These of course include the small members of large spot-groups. With the aid of a parallel-plate micrometer it has also been possible to measure visually the strength of the magnetic fields in a large percentage of these spots.

Throughout the year a new system of recording has been employed. All spots of the 16-inch solar image at the focus of the 150-foot tower telescope are traced on a large sheet of paper, and their polarities and field-strengths are also indicated on the drawing. Thus our present records are much more complete than those obtained formerly.

In spite of the peculiarities of complex spot-groups, in which the simple features of bipolar spots are frequently lacking, the fact remains that bipolar structure is almost invariably observed. That is to say, most spot-groups, however complex, can be divided into two regions of opposite magnetic polarity, though it sometimes happens that minor companion spots are not of the expected sign. Cases are not uncommon in which a second bipolar group, or one of its members,

appears close beside another group. These deserve careful study in the future.

Classifying the spots on the bipolar basis, and counting single spots as though they were the preceding members of such groups, Mr. Nicholson has tabulated their polarities as shown in the table. The data include all spots whose polarities were observed during the years 1913 to 1916, inclusive. The term "regular" as applied to the polarity of spots or the direction of whirl in the overlying *Hα* flocculi indicate that the observations thus designated are in harmony with the rule given in the last report.

Hemisphere.	Direction of *Hα* whirl.				Polarity.		
	Regular.	Irregular.	None.	Undetermined.	Regular.	Irregular.	Undetermined.
North............	87	24	50	148	257	10	42
South............	68	20	22	135	202	8	35
Whole sun	155	44	72	283	459	18	77

It will be observed that in the case of spot polarities the number of exceptions to the rule is small—18 in a total of 459. Of these, 8 are of the spot type classed by the Greenwich observers as "faint markings"; 3 of the remaining 10 were observed on one day only, without check observations; and 1 was a complex group in which the largest member was regular. The flocculi, however, are much less uniform in behavior. The exceptional cases should prove of great interest.

As stated last year, the polarities of the spots reversed at the spot minimum, while the direction of the *Hα* flocculi showed no change. An interesting case is afforded by a photograph in which two single spots of the same polarity, widely separated on the solar surface, are accompanied by *Hα* flocculi indicating opposite directions of whirl. The sun-spot maximum has hardly yet been reached, but if any reversal of polarities is to occur at that time, no indication of it has yet been detected.

"HYDROGEN BOMBS" NEAR SUN-SPOTS.

Observations made in previous years on the great widening of *Hα* in small eruptive regions in the penumbra, or at other points near active sun-spots, have been frequently repeated. The regions in question are very small, usually only a few seconds of arc in diameter. The narrow *bright* wings of *Hα* corresponding to them frequently extend several angstroms on either side, fading in intensity toward their extremities. Mr. Ellerman has recently succeeded in making some good photographs of these spectral phenomena, which are very short-lived.

GENERAL MAGNETIC FIELD OF THE SUN.

The investigation for determining the inclination of the sun's magnetic axis and the period of its revolution about the solar axis of rotation has been continued; 632 spectra have been measured by Mr. van Maanen, representing observations on 19 days. The work, which has involved the measurement of 2,132 plates during the last three years, is now nearing completion. From observations on 63 days, distributed over an interval of 110 days for which plates are available, new values for the inclination and the period have been derived. The reduction of the measures and the necessary computations were made by Miss Wolfe under the superintendence of Mr. Seares. The results are:

Period $= 31^{d}.79 \pm 0^{d}.31$ Inclination $= 6^{\circ}.2 \pm 0^{\circ}.4$
Magnetic pole on central meridian, 1914, June 25.31 ± 0.42 G. M. T.

The data give some indication that the inclination is not constant; this, however, may be due to accidental errors or possibly to the influence of spots and those features which have been called "faint markings" by the Greenwich observers, though none of these were seen when the photographs were taken. In general, days on which spots were near the sun's meridian were avoided. To investigate the influence of the "faint markings," some photographs of their spectra have been taken; measures of a few of these show rather strong magnetic fields, of the order of 100 to 150 gausses. It is clear that if many of these local fields were present when the plates were taken for the investigation of the position of the sun's magnetic axis, they may have been a disturbing factor in the derivation of the inclination. It will therefore be necessary to see if these markings, first mentioned by the Greenwich observers in January 1915, are visible near the spot minimum or appear only during the time of increasing activity.

THE EQUIVALENCE PRINCIPLE OF RELATIVITY.

Mr. St. John's investigations on the accurate determination of the positions of solar and terrestrial lines have been utilized in several specific problems, among them a test of the relativity hypothesis as applied to the solar atmosphere.

According to Einstein's generalized equivalence principle of relativity, the lines in solar and stellar spectra should be displaced to the red when referred to the corresponding terrestrial lines. The calculated displacements, equivalent in the case of the sun to the Doppler effect of a velocity of 0.634 km. per sec., are well within the range of solar measurements. An extended investigation based upon the behavior of lines in the nitrogen (cyanogen) band at λ 3883 was undertaken to determine what consideration should be given to this deduction from the equivalence principle in the interpretation of observations of solar spectra. These lines lend themselves to the purpose, as they are not displaced by pressure; freedom from Doppler effect is obtained by making the

observations at the polar limb. Emphasis was placed upon the selection of the lines used, with a view to precision of measurement and freedom from blends. The wave-lengths were measured at the sun's center and limb and in the carbon arc in terms of identical iron standards, and their solar wave-lengths were redetermined on the Rowland system. The displacements, sun *minus* arc, were determined at the center by direct comparison and by three indirect methods; the displacements, limb *minus* arc, were derived by two methods, with results as shown by the table.

No. lines.	Intensity.	At center.	At limb.
25	00 to 1	−0.0009	....
18	2 to 4	+0.0013	....
17	00 to 1	....	0.0000
18	2 to 4	....	+0.0036

The observations of greater weight, those upon low-level lines of intensity 00 to 1, indicate a slight upward movement of the vapor over the center of the disk. A possible explanation from the relativity point of view is that the displacement toward the red has been overbalanced by a Doppler effect; but at the limb, where the Doppler effect of such a motion would be zero, the solar and arc wave-lengths are equal.

If the means for all lines be considered, the displacement at the center of the disk is zero and at the limb 0.0018 Å toward the red. Within the limits of error there is accordingly no evidence in these observations of displacements in the direction of longer wave-lengths, either at center or at limb, of the order of the 0.008 Å required by the equivalence principle of relativity as developed by Einstein.

ERRORS IN THE MEASUREMENT OF CLOSELY GROUPED LINES.

A further investigation of the errors incidental to the measurement of pairs of closely adjacent lines is being carried on by Mr. St. John with the aid of artificial complexes in which the actual separation and relative intensities of the components are known. This promises to yield results valuable for solar work, as the appearance of combinations of solar lines can be simulated with a high degree of perfection. Preliminary data show that for a doublet in which the maximum of one component coincides with the first minimum of the other (the usually accepted limit of spectrographic resolution), the measured separation is 0.430 mm., while the actual separation is 0.380 mm. The combination reproduces approximately the appearance and scale of a solar pair in a fifth-order spectrogram of the 30-foot spectrograph separated 0.1 Å. The error represents an over-separation of 0.013 Å, a confirmation of the previous determination of the errors in the Rowland table

for close pairs. The investigation promises a means of fixing the limits beyond which the measurements of an individual observer are reliable and of determining approximately his systematic error within such limits.

The multiplicity of causes which may be concerned in the displacement of lines in terrestrial and solar spectra rendered much preliminary investigation necessary before a hopeful attack could be made upon the problems involved. Investigations of the preceding year showed that, within the limits of error, systematic effects of anomalous refraction are absent from the general disk of the sun, while those of the present year have shown the absence of displacements required by the equivalence principle of relativity, and have developed a source of iron lines free from the disturbing influences of pole effect. By the elimination of anomalous refraction and relativity, and the development of a source by comparison with which the relative displacements of the iron lines in solar and arc spectra may be referred to conditions in the solar atmosphere, it is possible to attack the related solar problems with greater prospect of success.

It becomes increasingly evident that data based upon several elements and covering an extended range of wave-length will be necessary for definitive determinations, and that further investigation should be made of conditions obtaining near the solar limb. Investigations now in progress bear upon these questions and have for an immediate end the establishment of a system of solar standards in terms of international units. These standards will eventually be derived from three sets of observations, for which an interferometer and two spectrographs are available.

SOLAR ROTATION.

The series of plates at solar latitudes 0° and 45° is being continued with the 150-foot tower telescope, with the object of obtaining observations over an extended period under as nearly as possible the same instrumental conditions. In view of the differences found by observers, it is desirable to have a long homogeneous series for determining whether the indicated variations in solar rotation period are real or depend upon instrumental conditions and personal equation. Observations with the 150-foot telescope will be compared with simultaneous observations made with a duplicate prism system used, sometimes with the 60-foot tower telescope and sometimes with the 60-foot Snow instrument, the advantage of the latter being the complete achromatism of the solar image.

The total variation found in the results for the years 1914, 1915, 1916, and 1917 is about 3 per cent. This difference, however, is not between the values for the extreme dates and can not be ascribed to a secular or long-period variation in the rotation rate. It is probably due, in part at least, to local drifts in the sun's reversing layer.

The question whether atmospheric haze and scattered light can influence the results obtained in solar rotation observations has also been examined by Mr. St. John. Observations were made with the regular rotation apparatus and the 150-foot tower telescope, the light from a point 0.5 per cent of the radius outside the sun's limb being compared with that from a point 1.5 per cent within the limb, where the slit is set in the usual rotation observations. When the limb spectrum was fully exposed, there was no trace of a spectrum from the light outside the limb, and a factor of about 100 in the exposure times was necessary to obtain equality of densities. This is in agreement with the results found by Mr. Abbot, who, from observations on the distribution of light along the diameter of the solar image, concluded that the stray light from all sources at a point 1.5 per cent of the solar radius outside the limb is much less than 1 per cent of the sunlight at the limb for the region of the spectrum employed in rotation observations.

The measurement and reduction of the photographs required for these investigations by Mr. St. John have been carried out by Miss Ware and Miss Miller. Miss Ware has measured the solar-rotation negatives, while Miss Miller has dealt with those used in the study of the relativity effect.

INVESTIGATIONS OF STARS AND NEBULÆ.

OBSERVING CONDITIONS.

The weather conditions for night observations during the year ending August 31, 1917, were somewhat below normal. This was especially noticeable during the months of May and July, which were

Date.	Hours of dark-ness.	Hours clear.	Hours cloudy.	Hours lost silvering and repair-ing.	Hours of exposure time.	Observations.		
						All night.	Part of night.	None.
1916.								
September	295	226	69	0	173	21	4	5
October	336	191	145	0	149	15	6	10
November	330	221	95	14	156	13	10	7
December	346	168	178	0	127	10	7	14
1917.								
January	346	179	167	0	142	13	8	10
February	308	129	179	0	100	7	7	14
March	324	201	123	0	139	15	11	5
April	286	173	95	18	121	15	5	10
May	266	148	117	1	111	15	3	13
June	230	207	22	1	156	25	2	3
July	255	173	81	1	123	13	13	5
August	269	256	13	0	195	26	5	0
Totals	3,591	2,272	1,284	35	1,692	188	81	96

characterized by an exceptional amount of cloudiness. The 60-inch reflector was in use 188 entire nights and parts of 81 nights. No observations were made on 96 nights. Out of 3,591 hours of darkness the instrument was in use 2,272 hours, or 63 per cent of the time. The statistics for each month are given on the preceding page. The mirror was resilvered in November and April.

The total exposure time for the year was 75 per cent of the observing time and 47 per cent of the hours of darkness. The observing conditions as regards seeing (on a scale of 10) and wind velocity are given in the accompanying table:

Seeing.		Wind.	
1	45 nights.	Very high	24 nights.
2	35	Brisk	37
3	47	Moderate	50
4	61	Light	139
5	57	Calm	100
6	24		
7	7		
8	1		

A standard self-recording anemometer provided by the United States Weather Bureau was installed on Mount Wilson in April and has been in service since that time, furnishing continuous records of the wind velocity. Since May 1 the highest recorded velocity during any five minutes was 30 miles per hour on May 5. The average velocity May 1 to August 31 was 6.7 miles per hour.

The precipitation during the year was 28.41 inches, the largest amount occurring in January. The snowfall amounted to 72 inches. Much fog occurred during the spring months, especially in the month of May. The maximum temperature was 98° F. on June 17; the minimum 10° F. on January 16.

PHOTOGRAPHS OF NEBULÆ AND CLUSTERS.

Photographs of the following spiral nebulæ were made during the year by Mr. Ritchey at the primary focus of the 60-inch reflector; the exposure times varied from 80 minutes to 465 minutes: N. G. C. 628, 650, 891, 3031, 5194–5, 6412, 6946, 7331, 7814. A close group of five spiral nebulæ in Pegasus was also photographed.

An interesting feature of the results was the discovery by Mr. Ritchey of a star on the photograph of the spiral nebula N. G. C. 6946 which did not appear on five photographs taken between 1910 and 1916. Several additional negatives confirmed the reality of this nova. The star was of about the fourteenth magnitude on July 19, 1917, and about one magnitude fainter on July 27. It occurs in one of the outer arms of the spiral at a distance of 2′ from the nucleus. A spec-

trogram taken with very low dispersion and without a slit on August 16 indicates a fairly strong continuous spectrum upon which bright bands appear to be superposed.

The discovery of this nova led to a careful reexamination of other photographs of spiral nebulæ. As a result two stars were found near the center of the Andromeda Nebula which, in all probability, are also to be classed as novæ. Fortunately an extended series of photographs of this object taken in 1909 and 1910 was available. Both stars were invisible on a negative of August 13, 1909; were faint on a plate of September 12; became bright on September 15 and 16; then grew fainter and were just visible on November 7. They were not seen after that date. At maximum these stars were of about the sixteenth magnitude.

Mr. Shapley and Mr. Pease have each found one nova on our photographs of spirals, while Mrs. Isaac Roberts has found one on photographs taken by her late husband, and Dr. Curtis has found three on photographs made with the Crossley reflector. The further investigation of such objects will undoubtedly prove to be a matter of great importance in the study of spiral nebulæ.

Mr. Pease obtained during the year 30 photographs of the following nebulæ and star clusters, with exposures ranging from 15 minutes to 5 hours 30 minutes:

N. G. C.	Type.	N. G. C.	Type.
894-5	Spiral	6914	Not seen
1931	Gaseous	7048	Planetary
2366	Gaseous	7067	Group of stars (vis. obs.)
2903	Spiral	7129	Gaseous
3357	Nebulous star	7226	Group of stars (vis. obs.)
3367	Spiral	7240	Many small nebulæ, spirals, and nebulous spots
3379	Nucleus in circular nebulosity	7243	Group of stars (vis. obs.)
3384	Nucleus in elongated nebulosity	7436	Several very small spindle nebulæ
3389	Spiral	No. in Ind. Cat. I.	
3391	Spiral		
3395-6	Spiral	1363	Star field (vis. obs.)
6820	Gaseous	1369	Group of stars (vis. obs.)
6846	Small group of stars	1378	Not seen
6888	Gaseous	1470	Gaseous

The cluster photographs were mainly for the purpose of securing star counts, while those of the nebulæ were for classification and determination of type—whether spiral, gaseous, or planetary. Several visual observations are included as well.

A photograph of N. G. C. 1555, Hind's Variable Nebula, taken on November 27, 1916, when compared with earlier negatives, showed marked changes of form in the nebula. The most important difference was in that portion near the variable star T Tauri.

JUPITER'S NINTH SATELLITE.

Using the 1915 observations, an improved determination of the orbit of Jupiter's ninth satellite was made by Mr. Nicholson, and an ephemeris was computed for the 1916 opposition. The satellite was found near the computed place on four negatives taken by Mr. Shapley with the 60-inch reflector. Its position was measured on these plates and the orbit corrected by the aid of the observations at three oppositions, 1914, 1915, and 1916. The positions of three new asteroids were also obtained from the plates.

MEASUREMENTS OF PARALLAXES AND PROPER MOTIONS.

At the 80-foot focus of the 60-inch reflector 402 plates with 535 exposures were taken by Mr. van Maanen, as follows:

	Plates.	Exposures.
For parallax...........	289	418
For proper motion......	98	98
Miscellaneous..........	15	19

The measures and reductions for 20 parallax fields have been completed, thus giving a total of 54 finished fields. Most of the stars measured are of the later spectral types, of magnitudes 5 to 7, and of proper motions less than 0″.5 annually. The results for the first 50 fields have been discussed for systematic errors in several ways:

1. The parallaxes of the 396 comparison stars, arranged according to brightness, seem to indicate a systematic error of +0″.001 in the parallaxes of the principal stars.
2. The neglect of the quadratic terms of the coördinates of the comparison stars has caused no systematic error.
3. A comparison of five fields observed in common with other observers shows no appreciable error.
4. A comparison of the proper motions in right ascension derived here with those given by Boss indicates a systematic error of −0″.001.
5. A comparison of the Mount Wilson parallaxes with those derived from van Rhijn's tables gives a difference of +0″.007.
6. A comparison of 47 of the parallaxes with those determined by Mr. Adams by his spectroscopic method indicates an error of +0″.003.
7. A comparison with the mean of the parallaxes determined by other observers for 68 stars of the same spectral type, magnitude, and proper motion points to a systematic error of −0″.001.

The only large difference is revealed by the comparison with van Rhijn's tables; there are several reasons, however, for believing that this can not be wholly due to the Mount Wilson parallaxes. From all material available it is probable that the latter have no systematic error exceeding 0″.003.

Several nebulæ have been included in the observing program. The following values of their parallaxes have been determined for three fields:

N. G. C.	Type.	Relative π.	P. E.
5194	Spiral	0".000	±0".010
6720	Ring	+0.002	±0.005
7662	Planetary	+0.021	±0.004

The value for N. G. C. 5194 is preliminary, as it was derived from 10 exposures only. For Barnard's star of large proper motion the preliminary parallax, also from 10 exposures, is +0".519 ± 0".005.

During the middle of the night, when the parallax factors are too small for measures of distance, the work on stars of large proper motion has been continued. First-epoch plates have now been taken for 170 stars, while for 12 fields second-epoch plates have been secured. No new companions, except that of Pi 2^h 123, mentioned in the last report, have been found. It should be noted that most of the fields for which second-epoch plates have now been secured are those of stars with very large proper motions, whose fields have been under observation for considerable time; three of them were already known to have companions.

For the reduction of the parallax measures Mr. van Maanen has had the assistance of Miss Davis for part of the time, and, more recently, that of Miss Wolfe.

STELLAR PHOTOMETRY.

The observational part of the investigations in stellar photometry by Mr. Seares and Mr. Shapley includes 522 photographs, all made with the 60-inch reflector and distributed as follows: Selected Areas, 208; clusters, 189; variable stars, 55; color photographs of stars, 19; miscellaneous, 51.

Photographic Magnitudes for the Selected Areas.

So far as the original program is concerned, the observational part of this investigation, which is in the hands of Mr. Seares, is now prac-

Kind of photograph.	Photographic magnitudes.		Photovisual magnitudes.	
	Required.	Obtained.	Required.	Obtained.
Magnitude scale.....	556	474	111	59
Zone comparison....	276	226	72	10
Polar comparison....	92	68	74	15
Totals.........	924	768	257	84

tically completed. At the urgent request of Professor Kapteyn, however, an additional zone of 24 areas has been added, in order that he might be supplied with standards at $-15°$. This increases the number of regions to a total of 139. The table on the preceding page refers to the enlarged plan.

During the past year the extensive reductions involved in this investigation have been carried on by Miss Richmond, Miss Joyner, Miss Carolyn Burns, and Miss Winn, with occasional assistance from Miss Wolfe. With one or two exceptions, the measures of the diaphragm photographs now available have been finished. For 102 of the areas the reductions are complete up to and including the relative magnitudes; and for each of these regions Professor Kapteyn has been supplied with a sequence of standard magnitudes, which he is using for the reduction of the Durchmusterung photographs of the Selected Areas.

Photovisual Magnitudes for the Selected Areas.

The plans of Mr. Seares and Mr. Shapley for this investigation were outlined in the preceding report. Photographs have been obtained whenever the arrangement of the program for other photometric investigations permitted. As indicated by the table, about one-third of the photographic work has been finished.

Distribution of Stars with Respect to the Galactic Plane.

The increase in the number of the stars as the Milky Way is approached from either side is a fact long established, and for objects brighter than the eighth or ninth magnitudes there is substantial agreement in the amount of the galactic condensation found by different observers; for the fainter stars, however, the value of the concentration has until recently been affected with much uncertainty.

The photometric results for the Selected Areas are still incomplete, but those now available contribute materially to a more definite knowledge of stellar distribution. From counts of about 40,000 stars on photographs of 88 areas well distributed in galactic latitude, Mr. Seares has derived the relation between stellar density and latitude for the magnitude limit of the plates, which provisionally is placed at 17.5 on the Mount Wilson photographic scale.

The data were first compared with the density tables of Kapteyn. The limiting magnitudes corresponding to the observed densities were interpolated from these tables and combined to form the mean limiting magnitude of the counts on the scale used by Kapteyn. The result, which is 16.3, deviates largely from the limit on the Mount Wilson system and indicates an important divergence of scale, but this is unimportant for the comparison. The differences between the logarithms of the observed numbers of stars and the numbers interpolated

from Kapteyn's tables for the average limit of 16.3 are in the second column of the accompanying table. Although systematic, these differences are small, and the Mount Wilson counts therefore agree with the results of Kapteyn in showing for the faint stars a high value of the galactic condensation.

Additional evidence is as follows: In his *First and Second Reports on the Progress of the Plan of the Selected Areas,* Kapteyn gives counts for 127,315 stars on 54 photographs of Southern Selected Areas made at Arequipa. The limiting magnitude for these photographs is practically the same as that for the Mount Wilson series. A comparison gives the differences in the third column of the table; these also are satisfactorily small. On the other hand, a similar comparison with the densities of Chapman and Melotte reveals the discordant results in the fourth column.

(Unit=0.01 in logarithm.)

Gal. lat.	MW *minus* Kapteyn.	MW *minus* SSA.	MW *minus* C and M.	Astrographic zones *minus* Kapteyn.				
				8.5	9.5	10.5	11.5	12.5
5°	− 5	+5	+74	−2	0	0	−2	−3
15	0	−3	+57	0	+2	+2	+2	+2
25	− 5	−7	+37	+1	+2	+4	+4	+4
35	− 7	−6	+29	+2	+1	+2	+2	+4
45	− 4	0	+28	+2	−2	−1	0	+2
55	+ 1	+4	+13	+1	−3	−3	−1	+2
65	+ 7	+5	+ 8	+1	−3	−3	0	+2
80	+12	(+4)	+ 4	0	−1	+1	−1	−1

A very valuable mass of data, including counts of about 600,000 stars from zones of the *Astrographic Catalogue,* has recently been collected by Turner. These also have been reduced to densities and compared with Kapteyn, and the differences in the logarithms for various magnitude limits on the scale of *Groningen Publication* No. 18 are in the last five columns of the table. The faintest limit is here only 12.5, but this is well below the point at which Kapteyn's densities begin to diverge from those of Chapman and Melotte; the astrographic counts are especially valuable as evidence on the distribution of stars of intermediate brightness.

Although the magnitude scale of *Groningen Publication* No. 18 seems to require some correction, these various comparisons afford a striking confirmation to the sixteenth magnitude (Groningen scale) of the values of the galactic condensation found by Kapteyn. It is a characteristic feature of his results that the condensation increases rapidly with increasing magnitude, so that for the limit mentioned the number of stars in the Milky Way is from 20 to 30 times that at the galactic poles.

Investigations of Star Clusters.

The study of magnitudes in clusters by Mr. Shapley has led to a number of results that indicate the advantage, for certain astrophysical problems, of dealing with large stellar systems from a point outside the system. Thus we may hope eventually to obtain fairly precise information concerning the size and form of the typical clusters and the distribution of stars within them. We may determine the relative frequency of stars of different absolute luminosities and colors, as well as the relationship of color classes to magnitude and to distance from a center of attraction. Such results for clusters will be directly applicable, at least in part, to similar problems in the general galactic system.

The investigation of magnitudes and colors in the globular clusters that contain typical short-period variable stars has suggested a method of estimating, apparently with considerable accuracy, the relative distances of globular clusters. Since these objects are widely distributed over one hemisphere and relatively are very remote, the method affords an indication of the distance to which the visible stellar universe extends. Although the periods, ranges, and maximum magnitudes of the variables differ, their median magnitudes are constant for each cluster, though they vary from one system to another. Moreover, the median magnitude appears to be definitely related to the magnitudes of the brightest stars in the cluster. If the obvious assumption that differences in the median magnitudes are due entirely to distance is correct, then not only can we derive relative parallaxes as soon as the apparent magnitudes have been measured, but, with the derivation of a value for the actual luminosity of such variables, we can also obtain very accurate absolute distances for all clusters containing typical variables, as well as for the isolated variables of this class.

In collaboration with Mr. Pease, an investigation has been made of the distribution of stars in 12 globular clusters. The main outcome is the discovery that an elliptical arrangement of stars is a general characteristic of photographs of such systems. Though rarely apparent among the brighter stars, the elongation is revealed when the star counts are extended to the fainter objects and examined with respect to direction from the center. For example, from one plate of Messier 13 the number of stars for successive intervals of position angle is as shown herewith.

Sector.	No. of stars.
15°	749
45	770
75	913
105	1,008
135	1,026
165	853
195	779
225	804
255	974
285	1,011
315	963
345	763

The two maxima in the series of numbers define the axis of elongation where the stars are 30 per cent more numerous than along the minor axis. A simple interpretation of the phenomenon is that the stars in the so-called globular clusters are distributed throughout a more or less flattened spheroid, whose projection on the celestial

sphere gives the observed elliptical distribution. This explanation is supported by the observed high concentration in certain clusters of blue stars and variables along the major axis, in close analogy with well-known phenomena of the galactic system.

Other cluster investigations have concerned the variable stars in Messier 3 and Messier 5. In the latter a search is being made into the colors and color variations of a group of variables with extremely short periods, discovered by Bailey at Harvard. Catalogues of magnitudes and colors have been published for Messier 11 and for four fields in the neighboring dense galactic clouds. Work on a dozen other clusters in and out of the Milky Way verifies the absence of effectual scattering of light in space, and permits a provisional estimate of the depth of the Milky Way as not less than 25,000 light-years in some directions. A study of the magnitudes of 900 stars in Messier 3 is nearing completion. In the search for very faint globular systems, the general character of a number of faint clusters has been examined. With a small photographic lens of 4 inches focal length the measurement of the integrated light of all the brighter globular clusters is under way.

Variable Stars and Miscellaneous Photometry.

Several miscellaneous investigations of variable stars by Mr. and Mrs. Shapley have been completed during the year, among which are the derivation of a color curve for XZ Cygni, the study of the orbits of some eclipsing binaries, and an inquiry into the magnitude and color of RU Boötis, one of the faintest of known periodic variables. Results for the last indicate a distance from the galactic plane several times greater than any heretofore found. Preliminary determinations show that the faintest variable stars in the Milky Way are red. In conjunction with Dr. van der Bilt, new light elements have been derived for W Ursæ Majoris, an eclipsing star remarkable for its very high density and short period. The analysis involved 67 minima, covering an interval of 13 years, and brought to light a small perturbation of the period. Measurement of the magnitude of the ninth satellite of Jupiter indicates that its diameter can not exceed 18 miles, if its albedo is comparable with that of the asteroids. A similar investigation of a faint asteroid, whose orbit has been computed by Mr. Nicholson and Mr. Shapley, shows it to have a diameter of approximately 3 miles; it is accordingly the smallest planetary object for which dimensions have yet been estimated. For the reductions connected with these various studies, Mr. Shapley has had the assistance of Miss Davis and, for a part of the time, that of Miss Richmond.

STELLAR SPECTROSCOPY.

The further development by Mr. Adams of the method of determining the absolute magnitudes of stars and their distances through a study of their spectra has led to some modifications of the observing program

during the past year. Since each photograph of a stellar spectrum provides the means of determining the star's intrinsic brightness in addition to its radial velocity, it has seemed desirable to extend the observations to include such of the brighter stars as may be investigated in this way. Accordingly all of the stars catalogued in the *American Ephemeris* with spectral types between F0 and M have been added to the observing list.

Observations have been continued on the fainter stars with measured trigonometrical parallaxes, and this list is now nearly completed. Numerous stars of large proper motion are being investigated for luminosity and radial velocity and are proving to be objects of exceptional interest from both points of view. In addition, a considerable number of stars of small proper motion with magnitudes fainter than 6.0 has been included in the observing program. In the case of the very faint stars increasing use has been made of the 18 cm. camera. While the radial-velocity determinations obtained from such small-scale photographs are necessarily subject to considerable uncertainty, it has been found possible to secure approximate results for numerous stars which could not be obtained otherwise. For absolute-magnitude estimations these photographs are of great value.

The number of spectrograms obtained during the year is 1,095, distributed as follows:

American Ephemeris stars	475
Large proper-motion and parallax stars	268
Small proper-motion stars	287
Miscellaneous	65

Of the photographs 156 were of stars fainter than the eighth magnitude on the visual scale.

Radial Velocities.

The radial velocities of 147 stars have been determined during the year from the measurement of three or more negatives, and one or more values are available for several hundred others. The inclusion of the brighter stars in the observing list has made it possible to compare many of the results with those obtained at other observatories, and a satisfactory degree of accordance has been found to exist. A few of the more interesting results for individual stars are as follows:

1. The spectroscopic binary Boss 46 proves to belong to the class having abnormal calcium lines. The hydrogen and helium lines show a velocity variation amounting to 485 km. with a period of 3.52 days. The calcium lines show a very slight variation or none at all.
2. Several high-velocity stars have been found. Of these the ninth-magnitude star A. G. Ber. 1866 shows a velocity of −190 km. The cluster-type variable SU Draconis has a velocity of −195 km. at maximum light.
3. Six new spectroscopic binaries have been discovered.

The most important application of the radial-velocity results has been to an investigation of the relationship between absolute magnitude and stellar motions carried out by Mr. Adams and Mr. Strömberg. For this purpose use was made of the absolute-magnitude determinations obtained spectroscopically, supplemented by luminosities derived with the aid of a modified formula connecting mean parallax and proper motion. A total of about 1,300 stars was used in the investigation. These were divided into groups situated in concentric zones about the sun within certain definite limits of parallax. A comparison of the radial motions of the stars within these groups indicates clearly an increase of velocity with decrease in absolute magnitude, independent of distance from the sun, which amounts to about 1.5 km. per unit of magnitude. A combination of the values for all the zones is shown in the accompanying table. M and V′ are the absolute magnitude and the radial velocity corrected for the solar motion.

F and G stars.			K and M stars.		
No.	M	V′	No.	M	V′
		km.			*km.*
188	0.3	11.2	125	0.5	14.6
193	1.3	13.6	164	1.4	16.6
189	3.0	14.9	124	2.5	20.6
84	5.1	17.3	74	7.0	26.9
29	6.8	21.2	13	10.0	30.0

This conclusion was further tested by the use of the velocities at right angles to the line of sight and very similar results were found. The variation with absolute magnitude is independent of the assumption of a frequency distribution of velocities in accordance with Maxwell's law, provided only that the law of distribution along the three components in space is the same. The influence of stream motion upon the results was also investigated and found to be relatively slight in the case of the stars employed. The fact that the fainter stars move more rapidly than the brighter seems, therefore, to be established definitely by this investigation.

Reference may be made to two additional products of this study of stellar magnitudes and motions. The first is the evidence that the average space velocity of the K and M type stars is about 1.0 to 1.5 km. greater than that of the F and G type stars of the same absolute magnitude. The second is the test of the accuracy of the spectroscopic determinations of parallax provided by the computation of the values derived from the stellar cross-motions; the comparison indicates close agreement for larger parallaxes and somewhat higher values than those computed in the case of the very small spectroscopic results.

A continuation and extension of this investigation is now being carried on by Mr. Strömberg. This will include a determination of the solar motion from groups of stars of different absolute magnitude, the relative effect of stream motion on stars of high and low luminosity, and a study of the velocities of stars of different intrinsic brightness with reference to the galactic plane. An interesting feature already shown by the investigation is the marked condensation of the high-luminosity stars of types F to M in the galactic plane, a result previously known to exist for the A and B stars.

Spectroscopic Determinations of Luminosity and Parallax.

The determination of the absolute magnitudes and the luminosities of stars from a study of their spectra by the method described in the report of last year has been continued by Mr. Adams and Mr. Joy, with the aid of the photographs of the stars observed for radial velocity. Magnitude determinations are now available for about 800 such stars, many of them with measured trigonometrical parallaxes. A list of 500 of these stars has been selected for publication; this includes stars for which several photographs have been obtained and a number of special interest, though with fewer observations. For 360 of these stars parallaxes have been determined in the usual way by various observers. A comparison of the results, spectroscopic *minus* directly measured values, is as follows:

Type.	No.	Systematic difference.	Mean deviation.
F0 –F8	88	+0″.006	0″.020
F9 –G7	91	+0.007	0.023
G8 –K2	96	–0.004	0.030
K3 –K9	57	+0.008	0.031
Ma –Md	28	+0.004	0.028
Total	360	+0.0037	0.026

There are 59 stars in the list with parallaxes measured by three or more observers. The systematic difference in the case of these stars is +0″.001. In view of this comparison it is probably not too much to state that the spectroscopic method, for all but the very largest parallaxes, is capable of yielding results of nearly the same order of accuracy as direct photographic methods with modern instruments.

Two extensions of the method have been made. The first is the use of certain additional spectral lines which has made it possible to include stars of types A8 to F5 in the investigation. The second is an attempt to derive criteria for the further subdivision of the dwarf M-type stars. Hitherto all the known stars of this type have been found to have nearly equal absolute magnitudes of about 10 to 11, but

the discovery by Professor Barnard of a star with an absolute magnitude of nearly 13.5 provides an opportunity to extend the search for spectral differences to fainter stars. Several other results of this investigation may be referred to briefly.

1. Abnormal intensity of the hydrogen lines is a characteristic of the highly luminous stars of the K and M types. This is probably related to the so-called giant and dwarf division among the stars.

2. This division is very clearly shown by a comparison of the numbers of stars of each absolute magnitude. It may be traced into the stars of the G and F types of spectrum, although it is possible that the selection of the observational material may influence the results to some extent in the case of these two types.

3. A clear correspondence is shown in the behavior of the lines which vary with luminosity in stars when examined in laboratory sources. The absolute-magnitude determinations, accordingly, may be ascribed directly to a physical basis.

4. High-luminosity stars are characterized by abnormally strong enhanced lines, and fainter stars by strong low-temperature lines. Lines used for absolute-magnitude determinations are included in this more general distinction.

The measurement and reduction of the photographs of stellar spectra have been carried on by Miss Burwell, Miss Stone, Miss Brayton, and Miss Shumway. In addition to radial-velocity measurements, Miss Burwell has assisted in all of the spectroscopic determinations of absolute magnitude and parallax.

NEBULAR SPECTROSCOPY.

A few photographs were obtained by Mr. Pease with the small spectrograph at the primary focus of the 60-inch reflector. An exposure of 85 hours on the Andromeda nebula with the slit set on the minor axis of the nebula, the multiple comparison spectrum device being employed, showed no appreciable rotational velocity. The radial velocity determined by Mr. Adams from this photograph is −300 km.

A spectrogram of the star cluster Messier 5, taken under very poor conditions of definition with an exposure time of 53 hours, indicates an F-type spectrum for three stars which appear on the plate.

A photograph of the spectrum of Nova Geminorum obtained in March 1917 shows the spectrum to be essentially identical with that of the previous year. It is of the Wolf-Rayet type and appears to be relatively permanent in character.

PHYSICAL LABORATORY.

BUILDING AND INSTRUMENTS.

The congested condition of the physical laboratory has been relieved by the construction of an addition by which the floor space was approximately doubled, the new portion having an area of 31 by 44 feet. The

addition contains two dark-rooms and an office, provides a more favorable installation for the interferometer spectrograph and space for a well to be excavated later for a plane-grating spectrograph of longer focus than that now in use. Three large instrument piers in the new portion are fitted with gas, water, and drain, as well as electrical connections. A large switchboard is being constructed, by means of which direct and alternating current at a variety of voltages can be supplied to all parts of the laboratory.

The auxiliary concave-grating spectrograph has been provided with a permanent mounting. Three concrete piers support the instrument and a substantial double-walled wooden housing affords efficient protection to the entire apparatus. After the adjustment of the instrument, curves giving the position of the camera and the focal setting for any wave-length were determined experimentally and found in good agreement with those calculated from the fundamental constants of the apparatus.

A new etalon embodying improvements indicated by our experience with the earlier types has been constructed, and the tests made have proved it to be highly satisfactory. The frame is entirely of steel, designed to give extreme stiffness and stability, and will accommodate plates of different thickness with separators of fused quartz up to 20 mm. in length. Six of these separators have been completed, having lengths of 2.5, 5, 7.5, 10, 15, and 20 mm. respectively. Under actual working conditions the apparatus is remarkably insensitive to thermal and mechanical disturbances—the whole order of interference is constant for a period of many weeks and the corrections necessary from time to time to insure parallelism of the plates are exceedingly minute.

The adjustment of the etalon is now carried out *in situ* with the aid of the long-focus mirror that, in actual use, projects the rings upon the slit, and after parallelism has been attained it is unnecessary to touch the instrument. Changes in thickness occurring during a day's observations amount, at a maximum, to only one part in a million.

A valuable addition to the electric equipment has been made by the purchase of a transformer of 10 kw. capacity, capable of potentials up to 120,000 volts. It is provided with a rotating contact device driven by a synchronous motor by which unidirectional discharges may be obtained; these are especially useful for high vacua.

A new arc-and-spark chamber has been built in the shop, for operating these sources either *in vacuo* or at pressures up to 5 atmospheres.

The small motor-generator set formerly used in the laboratory has been modified by exchanging the old generator giving 125 volts for a new one yielding 250 volts with a full-load output of 15 amperes. This serves admirably for operating arcs for wave-length and other precision purposes, and saves the losses formerly entailed by operating two large generators in series.

Two more adapters to permit the use of ordinary measuring machines for observing rectangular coördinates have been constructed. These are especially useful in the reduction of interferometer plates.

A small 200-line half-tone screen has been provided for use in the study of intensity distribution in spectral lines by the method of Nicholson and Merton, and a double logarithmic sector for obtaining the necessary steep intensity gradient has been constructed.

A simple glass mercury still and a new vacuum pump have been added to the laboratory equipment.

ANOMALOUS DISPERSION WITH THE ELECTRIC FURNACE.

The preliminary experiments on anomalous dispersion by Mr. King, mentioned in last year's report, showed the effectiveness of the electric furnace in producing this phenomenon, especially with vapors of the more refractory substances. A more extended investigation has been carried out during the past year, in the course of which 254 photographs were made in a study of the effect for 12 elements. In the spectra of iron, chromium, and titanium, the relative degree of anomalous dispersion was recorded for those lines which showed the effect, namely, 73 lines of iron, 47 of chromium, and 102 of titanium. This permitted a comparison of other lines with these lines of known behavior in the furnace under various conditions. Lines of special interest in the other spectra were studied in the same way.

The general conclusion was that the anomalous dispersion shown by a line is proportional to its strength in absorption, provided a proper prismatic distribution is present in the absorbing vapor. The greater prevalence of anomalous dispersion in the region of shorter wavelength appears to result from the greater absorptive power generally found for lines in this region. A point of special interest is the frequent inversion of the anomalous refractive effect for a line when the temperature is raised, indicating that the vapor prism absorbing such a line has been inverted, the stronger absorption now taking place in the cooler region above. At the same time, other lines, requiring higher temperature for their production, show anomalous dispersion of regular type. This simultaneous refraction in opposite directions for lines of different character occurred many times when two or more elements were vaporized together, and, in the case of calcium, even for lines of the same element, the low-temperature line λ 4227 showing an effect opposite to that simultaneously given by the H and K lines. The experiments have thus shown a dependence on the distribution of the radiating particles rather than on the density of the vapor as a whole. This conclusion was borne out by the observation of distinct anomalous dispersion for the band at λ 3883. On the assumption that this band is due to nitrogen alone, the results showed that the strongest absorption was given in the highly heated region, where the density of the gas was at a minimum.

GENERAL ELECTRIC-FURNACE EXPERIMENTS.

In addition to the investigation just described, 114 photographs of furnace spectra were made by Mr. King, chiefly of the spectra of iron, calcium, strontium, and barium, under various conditions of temperature, vapor-density, and surrounding atmosphere. The iron spectrum from λ 2800 to λ 6800 was photographed with the 15-foot concave grating spectrograph at temperatures of 1650°, 2000°, and 2350° C., these temperatures having been found to give the most decided differences in the spectrum. This material, with that previously obtained, will furnish a homogeneous classification of iron lines according to temperature change.

The use of the "furnace flame," produced by passing oxygen through the furnace tube during the vaporization of a metal, showed that oxidation does not decidedly modify the line spectrum of iron. The effects were more readily explained as the result of an altered distribution of the vapor. A comparison with published data on the flame spectrum of iron showed that temperature changes in the furnace can produce effects similar to those ascribed to chemical action in the flame.

The new photographs of the furnace spectra of calcium, strontium, and barium provided material as to temperature changes of important lines, and in the case of barium furnished interesting data as to line structure and the conditions which govern it. In this spectrum the lines given by the arc in air between λ 3000 and λ 3800 are in general so diffuse and unsymmetrical that no accurate measurements of wave-length can be made. Their structure in the vacuum furnace is so different from that in the arc as to present the appearance of a different spectrum. The diffuse arc lines become very sharp in the furnace and permit measures of high precision. Some, which in the arc are so hazy that no measurement has been attempted, become well defined in the furnace. Striking changes in structure also appear, a pair or triplet sometimes showing in the furnace instead of the single arc line. In case the furnace line is single, it is usually at the violet edge of the arc line, the displacements corresponding to a furnace difference of one atmosphere being very large. In the region in question the wave-lengths of 67 barium furnace lines were measured from iron standards, with a large gain both in number and accuracy over measurements possible in the arc spectrum. Tests under various conditions showed that the vacuum furnace at different temperatures gives always the same lines, but that at high temperature the stronger lines become unsymmetrical in the direction of the dissymmetry of the arc line. Increase of pressure in the furnace, however, gradually suppresses the extra components peculiar to lines in the vacuum spectrum. It appears that the structure of the arc line is due to a combination of high excitation and pressure, the former being the chief agent in causing the dissymmetry which gives rise to the wave-length differences.

The fact that the furnace lines permit of close measurement has made possible a comparison with the solar spectrum. In the case of 31 lines, the wave-lengths of barium lines in the furnace are in close agreement with faint unidentified lines of the solar spectrum. In cases where a line breaks up in the furnace into two or three components, the solar lines appear to correspond to these rather than to the line given by the arc in the air. This points to a reduced pressure and relatively weak excitation in the sun for the level at which these barium lines originate.

Analyses have been made for the spectra of two samples of rare earths suspected of containing new elements. While positive results have not been obtained, these and other experiments with furnace and arc have shown several strong lines in the ultra-violet which have not been identified in known spectra. The strongest of these agrees closely with an unidentified solar line. Extensions of stellar and nebular spectra in this region will be watched for evidences of the presence of these lines.

PRODUCTION OF SPECTRA BY CATHODE LUMINESCENCE.

The preliminary results on the excitation of metallic vapors through the bombardment by cathode rays, reported by Mr. King last year, were much extended by the experimental work of Miss Carter during the summer of 1916. Spectra of calcium and iron were obtained of sufficient richness to show what is to be expected from a source of this nature. The calcium spectrum was quite different in its features from that given by the usual sources, the various "single-line" series being strongest, followed by the series consisting of line-pairs, while the triplet series were relatively faint. The high intensity of λ 4227 was of special interest. The iron spectrum obtained showed comparatively few lines, these being lines that are strong in the furnace, arc, and spark. Stronger effects can doubtless be obtained by this method with the high-tension direct current supplied by the new transformer and rectifier. The work is again being taken up by Miss Carter, with the purpose of obtaining several of the more important spectra, so that the characteristics of intensity and structure of lines when thus excited may be definitely established.

INVESTIGATION OF THE STARK EFFECT.

The investigation of the Stark effect described in last year's report has been continued by Mr. Anderson. A plane-grating spectroscope giving intense spectra and fairly high dispersion (3 to 5 Å per mm.) was built and has been found very satisfactory. Displacements amounting to 0.01 or 0.02 Å can readily be detected, and the brightness is such that the exposure time need rarely exceed 30 minutes.

A vacuum chamber suitable for use with metals having high melting-points presented some experimental difficulties, but one was finally

devised which has worked well, and during the year some 100 or more spectrograms of iron, chromium, nickel, vanadium, titanium, and manganese have been secured. A general survey of the electric effect for chromium, nickel, and iron has been made with the following results:

1. The majority of the arc and spark lines shows no appreciable electric displacement or decomposition.
2. A few hazy arc lines of Cr and Ni are affected by the electric field, showing either displacement or decomposition.
3. The affected lines are relatively very intense in the field, especially after the cathode has been used for a few hours without coming in contact with air at pressures above a few millimeters.
4. In all, 74 affected lines ascribed to Cr, 8 to Fe, and about 12 to Ni have been recorded.
5. The relative intensity of all the lines in the electric field differs from that of the arc, spark, or furnace, and will no doubt be an interesting subject for future work.
6. A few of the affected Cr lines appear in the sun, and their study will make possible a determination of the upper limit of intensity of possible electric fields existing at this level in the solar atmosphere. Preliminary measures of these lines in sun-spots show no appreciable electric effect.

DEVELOPMENT OF THE PFUND ARC FOR STANDARD PURPOSES.

An extensive investigation by Mr. Babcock and Mr. St. John has had for its purpose the development of an improved source of secondary standards of wave-length, free from the disturbing influences of pole effect. The interference apparatus recently installed has proved of great service in this investigation. It possesses the important advantages found in complete achromatism of the mirror system and in comparative freedom from temperature disturbances resulting from the use of fused-quartz plates and separators in the etalons. By the use of large-scale interference rings and increased auxiliary dispersion an anticipated gain in accuracy has been reached. The evidence collected with this apparatus and with the 30-foot plane-grating spectrograph, confirmed by independent observations of sun-arc displacements with the instruments on Mount Wilson, has established the presence of pole effect in the international arc, the source adopted for the production of secondary standards of wave-length. Even in the center of this arc, displacements amounting on the average to 0.006 Å are found for unstable lines. It has also been shown that the center of the 6 mm. 6-ampere Pfund arc, formerly thought to be free from pole effect, is somewhat affected. Modified specifications have been developed, however, by means of which the uncertainties due to pole effect are eliminated. As a result, the unstable lines of iron may now safely be employed in astrophysical investigations far more widely

than heretofore. Within the limits of observational error, stable lines have been found to have the same wave-lengths in all the different forms of arcs which we have tested.

For the unstable lines the need of a definition of the fundamental wave-length has become evident. Provisionally it is defined as the wave-length free from displacements due to conditions in the arc itself, which are associated with proximity to the poles but extended in range by increase of current. Evidence that a fundamental state may be attained is furnished by three lines of investigation: change of arc length, of current strength, and of constituents of the negative pole. When no further variation in wave-length accompanies a change of any one of the variables, the other two being constant, it is assumed that the fundamental condition has been reached.

A study of the widths of iron lines in various sources has shown that at atmospheric pressure the Pfund arc with negative pole of carbon yields the narrowest lines, especially when operated at a length of 10 to 15 mm., with a current of 4 or 5 amperes. A close rival is found in the center of the 5-ampere 12 mm. Pfund arc, which is the source recommended by Mr. St. John and Mr. Babcock for the production of secondary standards of wave-length. The center of the international arc is far inferior in this regard, and many lines in it are widened to such an extent as to be wholly unsuited to interference measurements.

As a source of reference standards for the comparison of the relative intensities of spectral lines, the center of the 5-ampere 12 mm. Pfund arc is found to be superior to the other forms mentioned above. This is due to the fact that the unstable lines are well developed in it, but still have moderate intensity gradients from the center of the arc to the poles.

SECONDARY STANDARDS OF WAVE-LENGTH.

For reasons set forth above, namely, the need of fundamental wave-lengths for unstable lines and increased reproducibility for all classes of lines, it became necessary to determine secondary standards in the center of the 5-ampere 12 mm. Pfund arc. This has required a repetition of part of the work noted in the last annual report, although the majority of the measurements of early plates can still be used. Determination of wave-lengths by the interference method were discontinued until the completion of the study of sources, but the investigation is now well advanced under improved observing conditions; 37 new photographs, all from a source free from pole effect, are now being reduced. On these plates 506 iron lines between the limits λ 3370 and λ 5085 have been determined in terms of selected lines from the published list of secondary standards. The increased sharpness in the iron lines yielded by the source adopted for our work makes possible the use of higher orders of interference than have hitherto been employed, and this involves a considerable increase in the amount of work, not only

on account of the greater number of lines suitable for measurement, but also because of the additional plates which must be taken. Many of the poorest lines in the iron spectrum can be measured with high precision when free from pole effect. The methods of reduction have been simplified as far as is consistent with accuracy. Aside from the adjustment of the etalon, no observations are required except the measurement of two or three diameters for each line.

A study of the relative values of the wave-lengths of the stable secondary standards has led to the use of these instead of the red cadmium line. There is no doubt that the published wave-lengths of the stable lines are accurately corrected for phase change and nothing is to be gained by redetermining them, while the saving of labor is very great. We are not precluded from introducing our own values of the relative wave-lengths when these differ by small amounts from those published.

In the measurement and reduction of the numerous photographs required for the interferometer investigations, much assistance has been given by Miss Margherita Burns, who has devoted all her time to the work, and, during the latter part of the year, by Miss Brayton.

WAVE-LENGTHS OF IODINE ABSORPTION LINES.

In addition to the determination of wave-lengths of iron lines by the interference method, 20 absorption lines of iodine have also been measured by Mr. Babcock with high orders of interference in terms of selected iron standards. The iodine lines are among those which lie superposed upon iron lines and are valuable as reference marks in the spectrum.

WAVE-LENGTHS OF SPARK LINES.

A few interferometer plates have been reduced by Mr. Babcock for the purpose of comparing wave-lengths of iron lines in arc and spark. Lines of groups a and b are found to have the same wave-length in both sources, while those of group c_4 have slightly greater wave-lengths in the spark. Groups c_5 and d are shifted to the red about 0.007 Å in the spark and group e to the violet about 0.008 Å.

PRESSURE EFFECT FOR IRON.

A redetermination of the pressure effect for iron has been undertaken by Mr. Babcock, in view of the discovery that pole effect has played a part in most previous work on this subject. Observations are made *in vacuo*, at atmospheric pressure, and at a pressure of two atmospheres, with precautions to avoid the introduction of pole effect. The interference apparatus, admirably adapted for this work, will be mented by the 30-foot spectrograph. Although the data at hand are meager, it may be said that the values for the stable lines of iron are in good agreement with former determinations, but for the sensitive lines the displacements appear to be somewhat reduced.

INTENSITY DISTRIBUTION IN WIDE IRON LINES.

Preliminary work on this problem has been undertaken by Mr. Babcock by the method of Nicholson and Merton in conjunction with the 30-foot spectrograph. The photographs taken thus far serve to illustrate the technique of the process, but are not definitive. It is planned to adapt the apparatus for use in conjunction with the interference method on account of the high dispersion thus made available.

SENSIBILITY OF FOUCAULT KNIFE-EDGE TEST FOR OPTICAL SURFACES.

In an interferometer of the Fabry and Perot type, residual errors in planeness of the optical surfaces accumulate with the multiple reflections and set a definitive limit to the resolving power obtainable. Further improvements in this type of instrument thus depend largely on increase in accuracy of the surfaces and this in turn requires higher sensibility in the methods of testing. An investigation was undertaken by Mr. Anderson and Mr. Babcock to find how far the Foucault test could be relied on for surfaces of any size, with the result that it appears possible to detect a general curvature amounting to only 1/75 of a wave-length, without regard to the absolute size of the surface. The investigation was marked by unusual precautions to guard against the introduction of bias on the part of the observers.

CONSTRUCTION DIVISION.

DRAFTING AND DESIGN.

A large proportion of the work of the drafting department has been related to the 100-inch telescope and its accessories. Difficulties connected with the operation of the observing platform led to a re-design of this important adjunct to the instrument, and the progress of the erection has necessitated occasional modifications of some of the auxiliary apparatus. The spectrograph for use at the Cassegrain focus has been designed, together with one of the double-slide plate holders. The detail drawings have been completed for the right ascension and declination telescope controls, the two long-focus cages, and the Newtonian cage, with their mirror supports, and many other portions of the mounting and attachments.

In addition to the 100-inch telescope work, drawings for instruments include the following:

- Comparator for measurement of direct photographs 3.5 inches square.
- Diamond polishing machine.
- Pressure arc.
- Pitch micrometer, 6-inch inside and outside micrometers.

The drafting department has also made the drawings for extensions to the Monastery and the Pasadena Laboratory. Mr. Pease has continued in charge of this department and Mr. Nicholson has acted as chief draftsman.

THE OPTICAL SHOP.

The completion of the two convex mirrors used in conjunction with the 100-inch mirror in the Cassegrain and coudé combinations occupied the first part of the year in the optical shop, which has remained under the charge of Mr. Ritchey. These mirrors, after being ground and polished to a spherical form, were hyperbolized with the aid of the large mirror. The 60-inch plane mirror was utilized to reflect the parallel beam, and, by a slight rotation of this mirror, the field at the equivalent focus of the system could be examined at any desired distance from the axis.

As soon as the work of figuring the convex mirrors had been finished, there was no further necessity for retaining the 100-inch mirror in Pasadena. Arrangements were accordingly made for its transportation to Mount Wilson, and this operation was carried out early in July. The mirror was crated in a strong box lined with building paper and supported on its edge by a heavy frame-work bolted to the bed of the motor truck. To reduce the amount of vibration, numerous springs were inserted between the box and the frame-work. The top of the mirror box when placed on the truck was about 14 feet from the ground and its weight, including the support, was 7.5 tons. The trip up the mountain was made without incident, the specially geared truck performing its work without difficulty.

The two large oval plane mirrors to be used in the 100-inch telescope have been shaped and fine-ground. One of these, the Newtonian flat, is exceptionally thick and its edge has been beveled in order to reduce the amount of intercepted light. Two mirrors 9 inches in diameter have been completed for use in the coudé form of the telescope when only the center of the field is employed. For spectroscopic work this will obviate the necessity of resilvering the large oval plane at frequent intervals.

Additional work in the optical shop has included two 12-inch plane mirrors for use in the Snow telescope spectrograph, several speculum metal planes for diffraction gratings, and six small mirrors for special experiments.

INSTRUMENT SHOP.

The work of the instrument shop, as in previous years, has been under the direction of Mr. Ayers, foreman, with Mr. Jacomini as chief instrument maker. Much difficulty has been encountered in securing a suitable end-thrust bearing for the ruling-machine, the artificial rubies used for this purpose frequently breaking down, owing to minute flaws and bubbles near the surface. Recent experiments, however, give promise of a solution of this problem. Mr. Jacomini has also given much time to questions connected with the erection of the 100-inch telescope; the cutting of the large driving worm-wheel has been carried out under his supervision.

Over 40 per cent of the work of the instrument shop has been connected with the 100-inch telescope, the construction of the three additional mirror cages being the largest single item. Among other important undertakings, reference may be made to the following: attachments to Snow cœlostat and to 30-foot spectrograph for the Snow telescope, auxiliary apparatus for the 10-inch refractor, a stellar comparator, pressure arc, vacuum pump, diamond polishing-machine, dividing engine, and two small grinding and polishing machines for optical work. Since July 1 almost the entire time of the instrument shop has been given to the construction of precision micrometers for the use of the Government.

ONE-HUNDRED-INCH TELESCOPE.

The completion of the building and dome for the 100-inch telescope in the summer of 1916 left the erection of the mounting as the chief outstanding problem in connection with the instrument. This has been in progress throughout the year under the direction of Mr. Sherburne. For reasons given in the last report, it was impracticable to assemble completely the mounting at the Fore River Works. As a result it has been necessary to proceed rather slowly with the erection and to fit and drill many of the members. Good progress has been made, however. The pedestals, mercury tanks and floats, the polar axis, and the tube are in place, and the rotation of the instrument on its bearings has been tested. The right ascension and declination slow and fast motions have been completed and attached, the large driving worm-wheel has been cut and partially ground, the mirror cell has been fitted, and the support system installed. The Cassegrain cage has been riveted together and ground true, and the mirror elevator has been assembled and tested. Although the work of erection must necessarily be somewhat delayed by the pressure of work in the Pasadena instrument shop, we hope to have the telescope ready for tests during the autumn.

The difficult and complicated task of wiring the instrument and dome, and the construction of the switchboards and much control apparatus of special design, has been in charge of Mr. Dowd, our engineer.

OTHER CONSTRUCTION WORK.

Two important pieces of construction work have been carried on under the supervision of Mr. Jones. The first was the addition to the Pasadena physical laboratory, completed during the winter. The crowded condition of the building and the necessity of providing space for additional apparatus have been recognized for several years. Fortunately the original building lent itself admirably to an extension and the floor space has thus been nearly doubled.

The approaching completion of the 100-inch telescope and the necessity of providing for additional observers on Mount Wilson has led

to the construction of a two-story concrete building adjacent to the Monastery. The building contains eight rooms and, so far as possible, will be devoted to the night observers, those engaged in solar work living in the Monastery itself.

Much general repair work has been done and many improvements to the instruments and buildings have been carried out. Several retaining walls have been built on Mount Wilson to prevent washing of some of the steeper slopes by the winter rains.

AN ELECTRIC-POWER TRANSMISSION-LINE TO MOUNT WILSON.

In the spring the Southern California Edison Company submitted a proposal to extend a transmission line up Mount Wilson for the supply of electric power to the Observatory and the hotel company. Terms of agreement were soon drawn up and construction work was begun in July. The line is now well advanced and should be in operation during the autumn. Since all of the electric motors used in connection with the instruments operate on direct current, a large motor-generator set has been installed in the power house to transform the alternating current into direct.

An abundance of electric power on the mountain will be of great value to the Observatory, not only for the operation of the instruments, but also for special investigations which involve the use of a powerful spark or an electric furnace. Probably it will also be utilized to some extent for domestic purposes at the Monastery. The present power plant will be maintained for use in emergencies and when the transmission line is out of service. The spectroheliograph and such other instruments as require a very constant current will be operated from the storage battery, this being charged by the motor-generator set.

NUTRITION LABORATORY.*

Francis G. Benedict, Director.

During the year the Nutrition Laboratory has had to modify its experimental procedures considerably, as a result of changes in personnel, loss of specially trained assistants, non-delivery of apparatus, and the pressing need of important economic problems. In the belief that the research character of the Institution should be retained so far as possible, every effort has been made to minimize procedures that would tend to convert the Laboratory prematurely into a testing or control station. The entire cessation of abstract research in most of the countries at war and the reduction in the amount of time available for research in the European neutral countries make it more and more important to continue our investigations as far as possible.

A misconception has naturally arisen with regard to the functions of this Laboratory, owing probably to the name attached to the Laboratory from its establishment. The designation "Nutrition Laboratory" was selected in the belief that the fundamental laws governing vital activity are the scientific bases of nutrition. That the first decade of the existence of this Laboratory has passed without any extended studies of the nutritional phases of the physiology of man, which are understood under the popular term of "nutrition investigations," is perhaps not surprising when it is stated that at the outset it was clearly recognized that the economic and sociological phases of the problems of nutrition were, we believed, more properly the province of the admirable organization centralized in Washington in the Office of Experiment Stations of the United States Department of Agriculture, which is in close touch with fifty or more important research centers in the several experiment stations. This is especially true of problems in nutrition in which the character of the diet, and atmospheric, industrial, social, and racial environments play an important rôle in the selection of food as well as the amount eaten. While this phase of nutrition investigations was emphasized by the late Professor W. O. Atwater in connection with his research work at Wesleyan University, Middletown, Connecticut, the establishment of the Nutrition Laboratory permitted a complete divorce of the more abstractly scientific phases of the problems of nutrition from the sociological and economic phases. Consequently, at the present time, the Nutrition Laboratory and its staff find themselves in great measure out of touch with the economic and sociological phases of the question, and many problems that would seem to be appropriately undertaken by this Laboratory are quite outside of our field of practice.

*Situated in Boston, Massachusetts.

For the first time in its history, therefore, the Laboratory appears to be to a certain extent misnamed. Respiration calorimeters, respiration apparatus, intricate gas-analysis apparatus, and special devices for physiological and psychological measurements do not lend themselves primarily to a study of the economic or sociological phases of nutrition problems. On the other hand, it is believed that the Laboratory is both morally obligated and well fitted to contribute somewhat to a solution of many of the important present-day problems. An extended investigation has therefore been projected in which the question of the physiological effect of a reduced ration upon a selected group of normal young men is to be studied in detail.

It is somewhat difficult to plan with absolute certainty any physiological experiments of an extended nature, using men as subjects, and it is obviously necessary to modify somewhat the plan of procedure as the research progresses. It can be seen that this projected study is of a character much more in line with those formerly carried out at Wesleyan University under the direction of Professor W. O. Atwater than the problems previously studied in the Nutrition Laboratory, for not only is it of prime physiological importance as an attempt to throw light upon the ability of the human organism to subsist upon a materially reduced ration, but it is also of direct economic importance.

While it has been the custom in the annual reports of this Laboratory to consider not only investigations actually in progress, but likewise those contemplated, emphasis is laid upon this new project primarily to call special attention to the fact that the main work of the Laboratory must still remain that of abstract research, and can wisely be diverted only in part to economic problems. As will be seen later in this report, although the Laboratory is not primarily adapted for the study of such problems, the staff is using every effort to utilize the resources of the Laboratory as may seem wise and feasible in helping to solve those of immediate national importance.

ADDITIONS TO EQUIPMENT.

APPARATUS FOR MEASURING TEMPERATURE OF COLD-BLOODED ANIMALS.

The slight differences between the body-temperature of cold-blooded animals and the temperature of their environment—differences which at times play a very important rôle in the metabolism of the animal—necessitate a fine degree of measurement. After preliminary experimentation, in which determination was made of the temperature between the coils of a large python, each respiration chamber was equipped with a thermal junction which gave the exact temperature of the environment and with a modification of the pyrovolter with appropriate galvanometers. This addition to our already extended equipment in the special laboratory at the New York Zoological Park makes it

possible to determine the true temperature of the environment in which these cold-blooded creatures are living during the experimental period.

CLINICAL RESPIRATION CHAMBER.

The success of the clinical respiration chamber in its use both at the Nutrition Laboratory and with diabetics at the New England Deaconess Hospital warranted the construction of a third chamber with special equipment for the measurement of the water of vaporization from the lungs and skin of the subject. In the new chamber oil is used instead of water as a seal. Lead pipes conduct the air to and from the air-purifying systems, and the bed and entire equipment inside the apparatus are of metal. Under these circumstances, the water vaporized from the lungs and skin may be measured with a high degree of accuracy. This is of special importance in experiments with nude subjects. As the apparatus is installed in a laboratory room which permits the regulation of the temperature, an opportunity is afforded for the study of the influence of temperature environment upon metabolism.

PORTABLE RESPIRATION APPARATUS.

The universal respiration apparatus, so extensively employed in this Laboratory, is not sufficiently portable for transportation even about the Laboratory or in hospital wards. The need for an apparatus that can be moved from ward to ward or from bedside to bedside led to the development in the past year of a new type of respiration apparatus in which the entire equipment is installed upon an upright stand with a substantial base mounted on universal castors. It can thus be quickly and easily moved from one place to another and readily adjusted for use. The subject can use either a mouthpiece or nosepiece attachment and remarkably free and even breathing is secured. The whole installation is simple and economical and the results obtained with it are confirmed by tests with the other standard types of apparatus. The demand for this apparatus has justified the Laboratory in departing from its custom of not constructing apparatus for sale. Seven portable respiration apparatus have been constructed during the past summer.

MINOR APPARATUS.

Minor additions to the equipment of the Laboratory include a very small double-string galvanometer, made by Dr. Miles, to be mounted upon a Williams-Hindle galvanometer and used as a signal apparatus; a camera arranged for continuous recording in the horizontal plane of long series of eyelid movements; and an exposure apparatus to provide peripheral points of stimulation for eye reactions embodying a group of 28 window and shutter devices. All of these are to be used in psychological research.

COOPERATING AND VISITING INVESTIGATORS.

As in previous years, Professor Elliott P. Joslin has cooperated in the research on severe diabetes in the respiration laboratory at the New England Deaconess Hospital. The equipment of a clinical laboratory in the hospital gives complete facilities for coordinated research on both the respiratory and urinary products in diabetes.

Dr. Fritz B. Talbot has continued his cooperation in the study of the metabolism of normal infants at the Directory for Wet Nurses of the Boston Infants' Hospital and will also cooperate in the investigation at another Boston institution in which the metabolism of normal children from 2 to 6 years of age will be studied.

Dr. J. Arthur Harris, of the Station for Experimental Evolution, Cold Spring Harbor, has supervised a statistical elaboration of published and unpublished data obtained in the Nutrition Laboratory, with the special purpose of determining physiological constants for normal individuals.

Numerous investigators have spent short periods for conference or experimental observation at the Laboratory; among others may be mentioned Dr. Paul Roth, of Battle Creek, Michigan; Dr. Roy G. Pearce, of Lakeside Hospital, Cleveland, Ohio; and Dr. Addison Gulick, of the University of Missouri.

INVESTIGATIONS IN PROGRESS.

METABOLISM DURING MUSCULAR WORK.

The study of the metabolism of man during walking, which was begun by Dr. Carl Tigerstedt and Dr. Hans Murschhauser in 1914 and since continued by Dr. H. M. Smith, was designed to include both the indirect and direct methods of heat measurement for horizontal and grade walking. That part of the study dealing with the indirect measurement has been completed and the work of compiling the results secured during grade walking has been continued, although subject to some interruption. It is hoped to have this part of the work completed by the end of the present year.

Preliminary to starting the series of tests for direct measurement of the heat evolved during walking, the large respiration calorimeter designed for such experiments has been thoroughly examined and the usual tests for tightness and electrical and alcohol check tests have been made with satisfactory results.

The treadmill used in the walking experiments, which will likewise be used in the respiration chamber, has also been carefully inspected and tested and some changes made to adapt it for the work in view.

For the series of experiments on heat-production during walking it has been found necessary to reconstruct the absorber table connected with the large calorimeter so as to permit much more thorough ventila-

tion of the respiration chamber and to provide for the absorption of the large amount of carbon dioxide present in this rapidly moving air-current. This has also necessitated the construction of a different type of carbon-dioxide absorber.

METABOLISM IN RECTAL FEEDING WITH ALCOHOL AND DEXTROSE.

During the past year the studies on metabolism after the ingestion of alcohol *per rectum* have been continued by Dr. T. M. Carpenter. Three control observations have been made and five observations with 500 c.c. of 7½ per cent alcohol. The observations were continued throughout the night and thus covered the period of deep sleep. The clinical respiration apparatus was used for measuring carbon-dioxide elimination, oxygen absorption, and the respiratory quotient. Continuous graphic records of pulse and respiration rates were made throughout the series.

A few additional experiments have been made on the absorption of dextrose administered by rectum.

A brief report of the effect of alcohol ingestion by rectum upon the respiratory exchange and the concentration of alcohol in the urine was given by Dr. Carpenter at the 1916 meeting of the American Federation of Biological Societies.

THE PSYCHOLOGICAL EFFECTS OF ALCOHOL GIVEN PER RECTUM.

The work of Dr. T. M. Carpenter on metabolism in rectal feeding with alcohol offered an excellent opportunity for Dr. W. R. Miles to pursue a correlated research on the psychological effects, using the same experimental subject before and after the metabolism sessions. The desirability of investigating the psychological effects of alcohol given by rectal injection during sleep is apparent, since by this method of dosage, if moderate doses are used and the concentration is not too great, it is entirely possible to keep the subject in complete ignorance as to the content of the dose. So far as we know, these are the first experiments in which this method has been employed and they are only the beginning of a more extended research along the same lines. The subject served a period of 1½ hours in the Psychological Laboratory in the evening immediately before going to Dr. Carpenter and again a like period in the morning when the psychological measurements were repeated. As in the intervening hours the subject was most of the time asleep and always lying quietly, the experiments contribute to the study of recuperation with and without alcohol.

INFLUENCE OF ALCOHOL UPON THE ELECTROCARDIOGRAM.

It was found feasible to arrange non-polarizable electrodes which could be comfortably worn by a subject who slept all night in the clinical respiration chamber. Such electrodes were in position during

some of Dr. Carpenter's all-night alcohol metabolism experiments when the subject was given alcohol by rectum. They interfered in no way with these experiments and made it possible for Dr. Miles to take electrocardiograms at desired intervals. Tracings from the three usual leads were taken every hour or oftener during the night. The total body and electrode resistance remained quite uniformly in the neighborhood of 2,000 ohms. The Williams-Hindle galvanometer was used. Complete records are available for five all-night sessions on this one subject. These records should contribute not only to the study of the influence of alcohol, but also towards determining any normal nocturnal variations of the electrocardiogram.

A STUDY OF PRACTICE IN EYE REACTIONS.

One of the unexpected features of the experimental results of Dodge and Benedict was the practice effect in reactions of the eye to peripheral stimuli. Previous to their experiments, no very extensive series of eye reactions by the photographic technique on unpracticed laboratory subjects had been taken by Professor Dodge and theoretically practice in this process was supposed to have almost reached its limit for adult subjects. Dr. Miles has lately made other forms of stimulus apparatus and has tested these intensively with a few subjects to determine the conditions under which practice effect is least prominent.

TESTING AVIATION RECRUITS.

Dr. Miles was requested to cooperate in making certain psychological measurements on aviation candidates, in order to develop methods and standards to serve in the preliminary selection of men to be trained in aviation by the United States Government. During the spring the facilities of the psychological laboratory were devoted to this work. Enlisted men taking their theoretical training at the Massachusetts Institute of Technology were subjects. The men were measured individually. Each subject served a period of $1\frac{1}{2}$ hours. The sessions were from 7 to 10 p. m. and followed the evening meal. Since the men were all physically fit, of about the same age, living under uniform military conditions, and not fatigued, the circumstances under which the measurements were made could hardly have been better. Incidentally this was an unusual opportunity to secure normal comparison data on the psychological measurements employed at the Nutrition Laboratory. The work on aviators is continuing.

METABOLISM IN DIABETES MELLITUS.

The installation of the special clinical respiration apparatus at the New England Deaconess Hospital and the assignment to the work there of the entire service of two assistants have permitted the study of selected cases of severe diabetes, both prior to and during the fasting

treatment, under the immediate direction of Dr. E. P. Joslin. The post-fasting period has presented many interesting features; the effect of the ingestion of levulose in varying amounts, particularly its effect upon the respiratory exchange, has also received special attention. The advent of the fasting treatment in diabetes has modified considerably the experimental procedure, and diabetics of the earlier well-recognized type are, or at least should be, rare. The details of the respiration apparatus experiments have been in the hands of Miss M. A. Corson, of the Nutrition Laboratory staff.

METABOLISM OF NORMAL INFANTS.

The importance of knowing the variations in metabolism during growth has led to a protracted study of the resting metabolism of several normal infants from birth until nearly two years of age. Dr. Talbot has most assiduously followed up these infants and has arranged, in spite of great obstacles, to have them come to the Directory for Wet Nurses of the Boston Infants' Hospital for observation of the respiratory exchange at intervals of two or three months. In addition to these prolonged studies, data with regard to normal infants from 1 to 2 years of age have been rapidly accumulated. The material thus obtained is so extensive that, for the present at least, it is believed we have sufficient data to establish a normal value for infants between birth and approximately 2 years of age. The apparatus has now been transferred to another Boston institution where older children may advantageously be studied, and it is proposed to continue the investigations by accumulating data regarding the metabolism of normal, healthy children from 2 to 9 years of age. The importance of this material can scarcely be overstated, when it is considered that the intelligent interpretation of the metabolism measurements in pathology can be made only when an adequate normal series is available.

CALORIMETRIC STUDIES DURING THE PROCESS OF FATTENING.

In the conversion of carbohydrate to fat, such as takes place in fattening animals like the goose and pig, certain relationships between oxygen consumption, carbon-dioxide production, and heat-production have been found extremely difficult of satisfactory explanation, thus implying some profound internal molecular rearrangements accompanied by energy transformations that as yet are too little understood. An extended series of observations, both on geese and a pig with surfeit feeding, has been carried out the past winter with a new type of respiration calorimeter and the assistance of Miss Alice Johnson. Numerous control experiments during the fasting periods and with an alcohol lamp have accompanied the entire series. The investigation is still being actively continued.

INFLUENCE OF ENVIRONMENTAL TEMPERATURE ON METABOLISM.

With the special form of clinical respiration chamber mentioned in the earlier part of this report, and the assistance of Miss M. F. Hendry and Miss I. A. Boles, an extended series of observations on the influence of temperature environment upon metabolism was made with a professional artist's model in the nude condition. The subject experienced no discomfort from environmental temperatures ranging from 15° C. (59° F.) to 30° C. (86° F.). Since the construction of the chamber permitted measurements of the water of vaporization and the gaseous exchange, apportionment of heat elimination between direct radiation and conduction on the one hand and vaporization of water on the other may be made. An elaborate temperature study, showing variations in the surface temperature of the subject in different experiments, accompanied the general investigation. The research is still in progress.

METABOLISM OF COLD-BLOODED ANIMALS.

The research at the New York Zoological Park has been most successfully continued with the assistance of Mr. E. L. Fox, whose fidelity to these tedious, time-consuming experiments, necessitating a constant stay in the laboratory for weeks at a time, has been especially productive of results. During the last year emphasis has been laid upon the digestive cycle of certain of the large snakes, particularly under different temperature environments. An unusual series of experiments has also been made with two Texas rattlesnakes, in which the temperature environment varied from 16° C. to 37° C. Aside from the suggestion that these experiments make in regard to the feeding requirements of different animals, they have great significance in interpreting some of the fundamental laws governing heat-production in the living organism. Although the laboratory equipment still remains in New York, the research has been temporarily suspended, owing to the cooperation of Mr. Fox in another investigation which, on account of war conditions, must receive prior attention. The study of the metabolism of cold-blooded animals will be resumed early in 1918.

ENERGY REQUIREMENTS OF NORMAL INDIVIDUALS DURING SIMPLE, ORDINARY ACTIVITIES.

While the basal resting metabolism of normal individuals may be adequately studied and, indeed, a large amount of such information is available, the metabolism of individuals performing simple household or other domestic movements is relatively little studied. In cooperation with the Department of Physiology of Simmons College, under the active leadership of Professor Alice F. Blood, a series of observations has been made on groups of young women ranging from 15 to 26 in number. These experiments have been carried out with the large respiration chamber, which permits the study of the metabolism of a

large group of individuals simultaneously. Thus far, the metabolism of a group of normal persons has been determined under the following conditions: Sitting quietly and reading; sitting quietly and singing; sitting quietly and reading aloud; standing quietly, standing up, and sitting down; dusting chairs. These investigations have been carried out with the assistance of Miss Alice Johnson and Miss Hendry and Miss Boles. We are also under obligations to the Domestic Science Department of the Boston Young Women's Christian Association for two series of experiments during the winter. The cooperation of Simmons College has been actively resumed and the accumulation of data should proceed rapidly.

NORMAL METABOLISM OF WOMEN.

The extended series of metabolism measurements made with humans of all ages has provided data for individuals of both sexes between the ages of 19 and 32 years, but measurements of metabolism of women over 50 years of age have been lacking. During the past winter especial attention has therefore been given by Miss M. A. Corson to securing normal women subjects over 50 years of age and a large number of such experiments have been successfully completed. A few experiments have also been made with men over 50 years of age. Thus data regarding the basal metabolism of normal individuals of both sexes for an important period of life are now available. The metabolism of women under 50 years of age has also been studied in a number of experiments to supplement the material already accumulated.

PUBLICATIONS.

The following publications have been issued during the year:

(1) Some psycho-physiological processes as affected by alcohol. W. R. Miles. Proc. Nat. Acad. Sci., 2, 703 (1916).

A preliminary communication giving briefly the results of a series of observations duplicating a series made with the same subject by Dodge and Benedict (Carnegie Inst. Wash. Pub. No. 232, 1915). The detailed results of this repetition series of experiments are now being prepared for publication.

(2) Physiological effects of ethyl alcohol when injected into the rectum with special reference to the gaseous exchange. T. M. Carpenter. Am. Journ. Physiol., 42, 605 (1917).

A brief abstract of the results of the experimental studies on rectal feeding with alcohol which were made in 1916.

(3) The absorption of alcohol and its concentration in the urine when injected by rectum. T. M. Carpenter and E. B. Babcock. Journ. Biol. Chem., 29; Proc. Soc. Biol. Chem., XXVIII (1917).

An abstract of the results obtained in studies made in 1915–16.

(4) Effect of alcohol on the respiration and the gaseous metabolism in man. Harold L. Higgins. Journ. Pharmacol. and Exp. Therapeutics, 9, 441 (1917).

In the study reported in this paper experiments were made on men, reclining and breakfastless, to determine the effect of 30 c.c. and 45 c.c. of ethyl alcohol

(suitably diluted but not as alcoholic beverages) on respiration and gaseous metabolism. Alcohol sometimes acted to increase the sensitivity of the respiratory center, as shown by a drop in the alveolar carbon-dioxide tension; sometimes alcohol was without action on the respiratory center. Alcohol did not have any broncho-constrictor action and seldom any broncho-dilator action, as shown from determination of the dead space of breathing. The respiration rate was not appreciably affected by alcohol nor was the type of respiration changed unless there was restlessness. The heat production, as indicated by the oxygen consumption, was ordinarily unchanged by alcohol; in about one-fifth of the experiments there was a rise in heat production of from 5 to 7 per cent. About 45 per cent of our experiments indicate a relative acceleration in pulse-rate after taking alcohol as compared to taking the control solution; in 55 per cent of the experiments this relative acceleration did not occur. Study of respiratory quotients obtained indicates: (1) 45 c.c. of alcohol is not burned at a faster rate than 30 c.c.; (2) probably 20 to 40 per cent of the total metabolism is due to alcohol; (3) if the rate of combustion continues at the same rate as in the first 2 or 3 hours, it requires 8 hours before all of the 30 c.c. alcohol and 12 hours before all of the 45 c.c. alcohol is completely burned. Alcohol diminished the volume of air breathed per minute in a majority of cases; this was due to diminished carbon-dioxide production.

(5) Physiology of the new-born infant. Fritz B. Talbot. Am. Journ. Diseases of Children, 13, 495 (1917).

The essential points of this paper may be summarized as follows: The respiratory quotients of new-born infants indicate that the supply of glycogen in the body is quickly used and that the energy is obtained in large part from the body-fat until the breast milk "comes in." The energy requirements of new-born infants are smaller per unit of body-weight than in older infants. The total calories of the basal metabolism of a new-born infant may be calculated from the formula: Total calories = length $\times$ 12.65 $\times$ body-surface. Chilling from exposure or a water bath depresses the metabolism and with it all the body functions. A new-born infant should not be bathed in water and great care should be taken that it is not chilled. Warm oil should be used to clean the body. Since a new-born infant is starved until the breast milk "comes in," weak or premature infants should be fed shortly after birth, preferably with the milk of another woman; but when this is lacking, a 5 per cent solution of some sugar, such as lactose, should be given as a temporary expedient.

(6) Twenty-four-hour metabolism of two normal infants with special reference to the total energy requirements of infants. Fritz B. Talbot. Am. Journ. Diseases of Children, 14, 25 (1917).

The purpose of this investigation was to determine how much extra energy was expended in the ordinary muscular activity of an infant during a 24-hour day. Normal infants in the Directory for Wet Nurses of the Boston Infants' Hospital were selected. The experimental periods began about 7 p. m. and continued for the subsequent 24 hours save for brief intermissions when the infant was removed and fed. The records in the 24-hour experiments were made in short periods, so that it would be possible to select periods of absolute quiet ("basal" metabolism) as well as periods of activity. Two experiments are reported; one of the infants remained inside the respiration chamber for a total of 22 hours and 31 minutes, the other 23 hours and 10 minutes. Muscular activity caused an increase of 67 and 70 per cent respectively in maximum heat-production as compared with basal heat-production. A rough estimate

of the daily caloric requirements of a normal infant may be made by adding to the basal metabolism the calories used by muscular activity. If the infant is very quiet, 15 per cent of the basal metabolism should be added, if normally active 25 per cent, and if extremely active about 40 per cent. To the result add 15 per cent for energy lost in the excreta and 20 per cent for growth. By this method of calculation it is estimated that the daily food requirements of the two infants studied are about 100 calories and 94 calories per kilogram of body-weight respectively. It is probable that infants fed on cow's milk, particularly on formulas containing large amounts of protein, will require even more food than infants fed on human milk, because the stimulating action of protein causes extra heat to be produced during digestion.

(7) **Food ingestion and energy transformations with special reference to the stimulating effect of nutrients.** Francis G. Benedict and Thorne M. Carpenter. Carnegie Inst. Wash. Pub. No. 261. (In press.)

This publication reports the results of an extensive series of observations with human subjects on the influence of the ingestion of food upon metabolism. During a period of some 10 years (1904–1915) data for the research were secured, first at Wesleyan University, Middletown, Connecticut, with the respiration calorimeter, and subsequently at the Nutrition Laboratory, Boston, Massachusetts, with the chair and bed calorimeters and two forms of respiration apparatus—the universal respiration apparatus and Tissot respiration apparatus.

Following an historical review of all previous investigations with man relating to food ingestion and energy transformations, an extended discussion is given of the necessity of establishing a suitable base-line upon which may be superimposed the factor of the ingestion of food. A critical examination is made of those factors liable to influence the determination of the basal metabolism, as muscular activity, sleep, condition of fasting, growth, climate, temperature environment, etc.; the advantages and disadvantages are considered of the three types of basal periods employed (basal periods of 24 hours' duration, of approximately 8 hours' duration, and of approximately 15 minutes' duration); the use of average basal values is likewise discussed.

Measurements of carbon-dioxide production, oxygen consumption, and heat-production, and in numerous instances records of pulse-rate, respiration-rate, and blood-pressure, were obtained with 39 male subjects in about 190 experiments. Studies were made of metabolism during chewing and after the ingestion of water, coffee, beef tea, and single food materials in which carbohydrate, fat, or protein predominated. A number of experiments were also made with combinations of food materials.

The conclusions drawn from the various groups of experiments may be summed up as follows:

1. The work of mastication, such as would be involved in chewing gum or a rubber stopper continuously, may temporarily require an increment in heat-production of approximately 17 per cent.

2. Ingestion of water with a temperature of either 22° C. or 55° C. produces no significant increment of the basal metabolism, if not over 500 grams of water are taken. With larger amounts of cold water there may be an increase which, in certain instances, has been found to amount to 16 per cent above the basal value.

3. Coffee, owing probably to its caffein content, acts as a stimulus to the metabolism. Approximately 325 grams of coffee at a temperature of about 60° C. will produce an increment in the metabolism of 8 to 9 per cent.

4. Beef tea, taken either hot or cold, slightly increases the metabolism.

5. With carbohydrates the basal metabolism may be increased to an average maximum of approximately 25 per cent by the ingestion of 100 grams of any one of several sugars, although levulose and sucrose appear to exert a somewhat more powerful influence than the other sugars. This increment occurs inside of 2 hours and the metabolism has a tendency to return to the base-line somewhat rapidly thereafter.

6. Ingestion of a diet containing a preponderance of fat produces a positive increment in metabolism, although this increment is considerably less than that observed with an equivalent amount of energy in either carbohydrate or protein.

7. Ingestion of protein in almost any quantity invariably produces an increase over the basal heat-production, which may be 25 per cent for several hours, and for short periods may rise to 45 per cent. No definite mathematical relationship between the amount of protein ingested and the increment in the total metabolism could be established in these experiments. No clearly defined difference between the animal and vegetable proteins was found in their influence upon the metabolism.

8. Experiments with mixed diets, especially those with excessive amounts of food, showed that by the ingestion of a large meal it was possible to stimulate metabolism to 40 per cent above the basal value for a number of hours, and to 20 per cent for at least 8 hours; indeed, there was every reason to believe that the stimulus to metabolism would have been found to continue considerably longer than the experimental period of 8 hours if the observations had been prolonged.

The "cost of digestion," or the mathematical relationship between the fuel value of the intake and the increase in heat-production due to the ingestion of food, is estimated with carbohydrates to be not far from 6 per cent on the average; with fat the increase is about 2 per cent of the fuel value of the intake, with a protein-rich diet approximately 12 per cent, and with mixed diets 6 per cent.

These experiments give no conclusive evidence regarding the cause of the rise in metabolism after food ingestion. Brief mention is made of the three prevailing explanations offered at present for this rise, *i. e.*, the "Verdauungsarbeit" theory of Zuntz and his associates, the specific-dynamic-action theory of Rubner, and the hypothesis that increase in heat-production is due to a stimulus to the cells as the result of products (probably of acid nature) obtained from the food materials ingested or elaborated from them. The present series of experiments can not be used as experimental evidence for any of the three current theories, although experience in the Nutrition Laboratory points rather strongly in favor of the theory of acid-body-stimuli. The report concludes with suggestions as to the best method for studying the effect upon the basal metabolism of the ingestion of food or drugs.

DEPARTMENT OF TERRESTRIAL MAGNETISM.*

L. A. Bauer, Director.

GENERAL SUMMARY.

OCEAN MAGNETIC WORK.

Volume III of the Researches of the Department, entitled "Ocean Magnetic Observations, 1905–1916, and Reports on Special Researches," was issued by the Institution in 1917. The volume consists of 456 pages, a frontispiece (view of the *Carnegie* under sail), 25 plates, and 35 text-figures. Reference may be made to that volume for the final results of the entire ocean magnetic work accomplished during the period 1905–1914, as also for the preliminary results for the period March 1915 to October 1916. Pages 259–264 of this report show the preliminary magnetic results for the period November 1916 to March 1917—that is, for the cruise of the *Carnegie* from San Francisco to Buenos Aires, where the vessel remained throughout the balance of the fiscal year.

There are thus now in print, and in form for immediate use by hydrographic establishments, the results of all of the ocean magnetic work for the entire period of 12 years, 1905–1917. Table 1 shows for each cruise of the *Galilee* and of the *Carnegie* the number of days at sea[1], the length of the cruise in nautical miles, and the number of observed values of the magnetic declination, inclination, and intensity of the Earth's magnetic field for the entire work, 1905–1917 (March). The subsequent columns give the average time-intervals, as well as the average distances apart, between the observations. The entries in the bottom row of the table summarize the work of the two vessels from August 1905 to March 1917. This table is an extension of table 72, given on page 358 of Volume III mentioned above. The portion added is for the period November 1916 to March 1917, San Francisco to Buenos Aires, the total distance sailed being 14,775 miles, at a daily average of 132 miles for the 112 days at sea, magnetic observations having been made daily (see page 250).

It will be seen from table 1 that the aggregate length of all cruises of the *Galilee* and of the *Carnegie* to March 2, 1917, is 239,224 nautical miles, or about 11 times the Earth's circumference. The average time-intervals and average distances apart for the *Galilee* work have been decreased by about 45 per cent in the *Carnegie* work. The increased efficiency, or productiveness, has resulted from the fact that the *Carnegie* is a non-magnetic vessel and because of the steady

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[1]In the case of the *Galilee* work, to the number of days at sea were added the days spent in the harbor-swings.

improvement in the instrumental appliances and observational methods. Magnetic observations on the *Carnegie*, as shown in table 1, are being obtained practically daily and at an average distance apart of 91 to 138 nautical miles.

TABLE 1.—*Summary of ocean magnetic work of the Galilee and the Carnegie 1905–1917* (*March*).

Vessel and cruise.	Number.		No. of observed values.			Average time-interval.			Average distance apart.		
	Days.	Miles.	Decl'n.	Incl'n.	Hor. int.	Decl'n.	Incl'n.	Hor. int.	Decl'n.	Incl'n.	Hor. int.
Galilee:						*days.*	*days.*	*days.*	*miles.*	*miles.*	*miles.*
Cruise I, 1905......	92	10,571	74	58	59	1.2	1.6	1.6	143	182	179
Cruise II, 1906.....	168	16,286	95	88	91	1.8	1.9	1.8	171	185	179
Cruise III, 1906–08.	334	36,977	156	169	171	2.1	2.0	2.0	237	219	216
Totals for *Galilee*.	594	63,834	325	315	321	1.8	1.9	1.9	196	203	199
Carnegie:											
Cruise I, 1909–10...	96	9,600	98	68	69	1.0	1.4	1.4	98	141	139
Cruise II, 1910–13..	798	92,829	858	648	643	0.9	1.2	1.2	108	143	144
Cruise III, 1914....	84	9,560	108	81	80	0.8	1.0	1.0	89	118	119
Cruise IV, 1915–17.	487	63,401	867	480	479	0.6	1.0	1.0	73	132	132
Totals for *Carnegie*.	1,465	175,390	1,931	1,277	1,271	0.8	1.1	1.2	91	137	138
Totals, *Galilee* and *Carnegie*.......	2,059	239,224	2,256	1,592	1,592	0.9	1.3	1.3	106	150	150

In accordance with the general plan of work, every opportunity is embraced, while the general magnetic survey of the Earth is in progress, to secure at the same time data regarding the *annual changes of the magnetic elements*. Such opportunities arise in the ocean work at intersections of the tracks of the *Carnegie*, for example, with her previous tracks or with those of the *Galilee*. Owing to the accuracy attained in the ocean magnetic work with the appliances and methods used in our work, it appears to be possible to determine the annual changes of the magnetic elements with a fair degree of certainty from the intersection of tracks about 4 or 5 years apart in time. Tables 3, 4, and 5, on pages 271–272, show the results thus obtained at sea by the Department of Terrestrial Magnetism up to the present year (1917).

It was found that the systematic errors in the magnetic charts, as reported upon in previous annual reports, were to be explained in large measure, at least for the magnetic-declination charts ("lines of equal magnetic variation"), as being due to lack of accurate information of the secular magnetic changes over the ocean areas. Usually constructors of magnetic charts have had to rely upon data obtained from more or less disturbed land observations along the coasts and on islands, or upon more or less uncertain sea observations, separated often by rather long intervals of time. Hence the value of the data determined from the observations of the *Galilee* and the *Carnegie*.

As a result of the magnetic observations made on the *Galilee* and the *Carnegie*, steady improvement in the magnetic charts of the various hydrographic bureaus is becoming increasingly manifest. The latest of these charts are the British Admiralty "Curves of Equal Magnetic Variation for 1917," in the construction of which credit is given to the Department of Terrestrial Magnetism for the "principal part of the new information now shown on these charts."

OCEAN ATMOSPHERIC-ELECTRIC WORK.

The first special report of Volume III (Researches of the Department of Terrestrial Magnetism), by L. A. Bauer and W. F. G. Swann, dealt with the results of the atmospheric-electric work on board the *Galilee*, 1907–1908, and on the *Carnegie*, 1909–1916 (April). From the beginning of the ocean work of the Department of Terrestrial Magnetism, it has been its aim to include in the program of scientific work whatever additional observational researches could be carried on advantageously and profitably without conflicting with the prime object assigned to the Department—the general magnetic survey of the globe. The problem which naturally suggests itself as closely related to that of terrestrial magnetism is that of terrestrial electricity, which embraces the following subjects: (*a*) the electric currents circulating within the Earth's crust; (*b*) the Earth's electric charge; (*c*) the conducting properties of the atmosphere. Subject (*a*) at present is one of combined laboratory and observatory investigation (see page 254). Subjects (*b*) and (*c*) together form the science termed "atmospheric electricity." It is with regard to ocean observations and results in the latter science that this special report concerns itself. A general electric survey of ocean areas possesses peculiar advantages over that of land areas, not merely because of the greatly preponderating extent of area, but because of the freedom from the disturbing influences of topographic and cultural features.

The Department's annual report for 1916 contained an abstract of the chief results obtained during the period 1907 to April 1916. During the summer of 1917 the discussion of the atmospheric-electric observations made aboard the *Carnegie* in the Pacific Ocean subsequent to April 1916 was continued under the immediate direction of Dr. Swann, who was assisted in this work chiefly by Dr. C. W. Hewlett. The latter was connected with the Department during the summer of 1917 as a research assistant, and began an investigation to determine the amount of radium contained in the sea-salt collected on the *Carnegie's* fourth cruise. The method of investigation used was that suggested by J. Joly. No such amount of radium in any of the samples collected on the *Carnegie* at sea, far away from land, was found comparable with that reported by certain former observers who used other methods and whose samples were obtained over sea areas comparatively near

land (see abstract, pages 274–276). In the forthcoming cruise the samples will be collected with the special view of affording information on the variation of radium-content with distance from land.

The general ocean atmospheric-electric results obtained since March 1916 only serve to strengthen the conclusion arrived at in Volume III. They show that, as a general rule, the atmospheric-electric elements are of the same order of magnitude at sea as on land, except as regards the radium-emanation content, which is much smaller on the ocean, and as regards the penetrating radiation, which is also smaller, as would be anticipated from the small value of the radioactive content.

Special attention has been devoted to the diurnal variation since March 1916, and the results for the diurnal variations of potential gradient, ionic content, and penetrating radiation can now be based upon about 20 sets taken over a complete period of a year. (See abstract, pages 281–283.)

LAND MAGNETIC WORK.

Though the war has prevented the completion of the magnetic survey of certain land areas for which plans had been made, the following work was accomplished during the period November 1, 1916, to October 31, 1917:

1. *Africa.*—An expedition, led by Observer H. E. Sawyer, through French Kongo along the Kongo and Ubangi rivers to Lake Tchad, thence eastward to Anglo-Egyptian Sudan.
2. *Asia.*—Expeditions by Observer F. Brown, under the direction of Dr. C. K. Edmunds, in Manchuria, southwest China, through the Yunnan province to Bhamo and across the Burma frontier, and finally along the southeast coast of China.
3. *Australasia.*—In connection with the establishment of the magnetic observatory in Western Australia, Observers W. F. Wallis and W. C. Parkinson made magnetic observations at various points.
4. *South America.*—Expeditions by Chief Magnetician Fleming and Observers D. M. Wise and B. Jones in the interior of Peru, both in connection with examination of sites for a proposed magnetic observatory in Peru and magnetic-survey work; also an expedition, led by Observer Allen Sterling, in Chile and Bolivia, thence down the Beni and Madeira rivers to Manaos, Brazil. Furthermore, Observers A. D. Power and L. L. Tanguy made magnetic observations at a number of stations in Argentina in cooperation with the Argentine Meteorological Office.

MAGNETIC OBSERVATORY WORK.

Western Australia.—The site finally selected for the magnetic observatory in Western Australia is about 10 miles west of Watheroo and about 120 miles north of Perth. The government of Western Australia, through the Minister for Lands and Agriculture, made a grant to the Institution of 160 acres for the building-site of the observatory, with

two additional 10-mile strips, 1 rod wide, for burying the cables to be used in investigations on earth-currents; the total area of the grant of land is approximately 220 acres. The observatory buildings are now in process of erection under the superintendence of Magnetician W. F. Wallis, assisted by Observer W. C. Parkinson. It is hoped that the observational work may be begun early in 1918.

Peru.—After considerable search and thorough examination of various regions in Peru, made by Chief Magnetician J. A. Fleming with the assistance of Observer D. M. Wise, a suitable observatory site near Huancayo, about 150 miles east of Lima, in the mountains, at an elevation of 11,000 feet, was found. The final acquirement of the site, as well as the erection of the observatory buildings, had to be postponed to some future date.

Washington.—Certain experimental work in terrestrial magnetism, atmospheric electricity, and on earth currents, conducted at Washington in connection with the observatory work proposed above, is described on pages 253–255.

RESEARCH WORK IN WASHINGTON.

TERRESTRIAL MAGNETISM.

Mention has already been made of the publication work in connection with the statement on the ocean magnetic work. The abstracts of papers and investigations, given on pages 269–284, will give further information under this head. Naturally there has been some curtailment of the regular work of the Department because of the assistance rendered by members of the staff to various governmental bureaus and to committees of the National Research Council in connection with problems of defense and research.

The next volume of the Department's Researches (No. IV), the preparation of which is well under way, is to contain the final results of the magnetic-survey work on land and at sea, 1914–1917. The observed results of the complete magnetic work on land and at sea for 1905–1917 will then have appeared in published form. It is hoped that Volume IV may be issued by the Institution in 1918.

A subsequent volume (probably No. V) will contain the results of all magnetic observations of the Department of Terrestrial Magnetism, referred to a common epoch; the construction of new world magnetic charts may then be successfully undertaken, as well as a new analysis of the Earth's magnetic field with its attendant greater problems. Portions of this volume are also under way.

Those engaged on the investigational and publication work besides the Director are: W. J. Peters, J. A. Fleming, J. P. Ault, H. W. Fisk, C. R. Duvall, and C. C. Ennis.

TERRESTRIAL ELECTRICITY.

Investigational work in atmospheric electricity and earth currents, preparatory to the inauguration of continuous observational work at the future magnetic observatories of the Department, was continued at the laboratory of the Department by Doctors W. F. G. Swann and S. J. Mauchly.

Dr. Mauchly's experiments on apparent vertical earth-currents, mentioned in last year's annual report, had concerned themselves with the investigation of the apparent changes in the electromotive force, produced when a long vertical tube containing earth, or salt solution, was turned through 180°. Since then Dr. Mauchly buried two pairs of electrodes in the ground, one pair being inclosed in an insulating tube and the other being free with corresponding electrodes, however, at the same level. Arrangements were made to record continuously the changes in electromotive force of the two pairs of electrodes and the temperature difference between the two levels concerned. As other duties permitted, the investigation was continued throughout the time that Dr. Mauchly was a member of the Physical Division. Among other things, correspondences between the indications of the two pairs of electrodes were shown to be of such a kind as to point out that the apparent diurnal variation of the "vertical earth-current" was, at any rate in part, a spurious effect resulting from diurnal variations in temperature between the electrodes.

Dr. Swann, assisted by Mr. Kotterman, had brought the design of the methods and instruments for the continuous registration of the potential gradient and the electric conductivity of the atmosphere to such a stage that on June 30, 1917, the further development and adaptation of the instruments to observatory use could be turned over to the Observatory Division, in charge of Chief Magnetician J. A. Fleming. Under the latter's direction and with the assistance of Dr. Mauchly, assistant chief of the Observatory Division since June 1, 1917, further good progress has been made and additional continuous records have been obtained.

The problem of the origin and maintenance of the Earth's electric charge has been given further consideration by Dr. Swann (see abstract, pp. 276–278). As time has permitted, he has also continued the investigation on the detection of single α particles shot out from the radium emanation in the air, and in connection with this investigation he has made certain experiments on a new form of plate for the unifilar-electrometer plates, the idea being to increase the stability and sensitivity of the instrument (see abstract, pp. 279–281).

INSTRUMENT WORK.

The following instruments were designed and constructed in the Department's instrument shop, which is a section of the Observatory Division under the charge of Mr. Fleming:

Marine inductor No. 7; declination and horizontal-intensity variometers for magnetograph sets Nos. 3 and 5, following in general the Eschenhagen type, and a new design for the vertical-intensity variometers was given consideration; new type of liquid-compass attachment to the dip circle for use on land and sea; special compensated earth-inductor and string galvanometer, designed by Dr. Swann; 12 special, universal pier-clamps for observatory use, and several pieces of experimental apparatus for the Physical and Observatory Divisions.

Universal magnetometer No. 14 and four Edelmann variometers were reconstructed. A new design for a marine moving-coil galvanometer and the construction of recording apparatuses for magnetograph sets Nos. 3, 4, and 5 are under way. The suspension arrangements of all the galvanometers used in the field with the magnetometer-inductors were modified for the use of quartz fiber instead of silk fiber; the new suspensions were found satisfactory, as shown by extensive use in the field, and constitute a material improvement over the older type. Some work was done for the Astrophysical Observatory of the Smithsonian Institution in connection with the construction of some special apparatus designed by Dr. C. G. Abbot.

The more important miscellaneous work included repairs and improvements upon instruments when returned from the field and improvements in machine-tool equipment. A special device for the construction and polishing of dip-needle pivots was designed and constructed by Mr. J. A. Widmer, chief instrument-maker, who also submitted a report upon the results of tests of various brass-lacquers, including a shellac lacquer made by the Department.

The small brass-foundry building, which as stated in last year's report became a necessity in order to secure absolutely nonmagnetic metals, was completed. The equipment includes two round, natural-draft coke furnaces, molder's bench, sink-tub, work-bench, pyrometer, and miscellaneous tools. Mr. C. Huff, instrument-maker, in charge of the brass-foundry work and experiments, reports that about 4,000 pounds of brass, aluminum, copper, lead, and zinc castings were made for field and observatory instruments and for special experimental appliances. This work was done by members of the existing force in the instrument shop who had had no previous experience in foundry work. As a result of numerous experiments and trials with various commercial fluxes, methods were evolved by which magnetically perfect castings can be made, even though the raw materials used for the alloys are not pure, thus solving a very important problem in the manufacture of magnetic instruments and one which has caused much difficulty in the past.

Owing to the large amount of work on hand for the instrument shop, it was not possible this year to undertake the construction of additional magnetic instruments desired by foreign governments. Besides the members of the instrument shop already mentioned in the preceding paragraphs, Messrs. E. K. Skonberg, G. H. Jung, and W. F. Steiner deserve mention for the excellent instrument work done by them during the year.

DETAILS OF OBSERVATIONAL WORK.

OCEAN WORK.

After a stay at San Francisco of five weeks, during which shore observations and instrumental comparisons were made and the vessel was overhauled and outfitted, the *Carnegie* left this port on November 1, 1916, bound for Easter Island. Light and variable winds were encountered until the vessel reached the northeast trade-wind region. In the calm belt near the equator, between the northeast and the southeast trades, continuous light airs from the south to southwest caused a delay of over two weeks and forced the vessel far to eastward of her intended route. The remainder of the voyage was made under good conditions and Easter Island was reached on December 24, 1916.

The stop at Easter Island was made in order to obtain magnetic data regarding secular changes, to secure a supply of fresh water, and to break the monotony of the long voyage from San Francisco to Buenos Aires. A magnetic station was established and a 24-hour series of declination readings was obtained. The party visited various points of interest on the island and obtained some valuable photographs of the large statues for which the island is particularly noted.

After taking on board a small supply of fresh water and provisions, the vessel sailed on January 2, 1917, for Buenos Aires. After leaving Easter Island adverse winds prevented the vessel from entering the unsurveyed area to the northeast, as had been planned. On January 19, 1917, Gambier Islands were passed. As no stop was contemplated, a small barrel, containing an abstract of all scientific results to date, was set adrift about one-half mile off the southeast entrance to Manga Reva Harbor.

Between January 22 and January 27 long and severe gales from the east to southeast were encountered. They were followed by two weeks of variable winds and weather, head-winds alternating with calms. When the vessel finally entered the region of the strong westerly winds, rapid progress was made toward Cape Horn. On February 16 the Diego Ramirez Islands were sighted as expected, and Cape Horn was passed the next morning. In the vicinity of Cape Horn the weather varied rapidly from one extreme to the other. The afternoon of February 16 was rainy and stormy, with a heavy gale from the northwest, but the evening was beautifully clear and almost calm. February 17 saw a repetition of the same change, the stormy weather ending early in the forenoon, the remainder of the day being clear and affording a fine view of Cape Horn and Tierra del Fuego. Owing to variable and adverse winds, some difficulty was experienced in weathering Staten Island and also the Falkland Islands later. The vessel passed to the westward of the latter group in order to avoid the icebergs and rough seas to the eastward.

On March 1, 1917, the Recalada lightship, at the mouth of the Plata River, was passed. After taking on the pilot the engine was started and the *Carnegie* went up the river under her own power, reaching Buenos Aires next morning, March 2, 1917.

As usual, observations for magnetic intensity and inclination at sea were made daily, regardless of conditions of sea or weather. Magnetic-declination results were obtained every day but four, which were too cloudy for these observations.

Tracks of the *Galilee* were crossed eleven times and the *Carnegie's* tracks of former cruises were crossed seven times, thus affording several opportunities for the determination of the annual changes in the magnetic elements for the regions covered. The total distance sailed was 14,775 miles, and the daily average for the 112 days at sea was 132 miles.

Shore observations and instrumental comparisons were made at the Argentine Magnetic Observatory located at Pilar. Comparisons had previously been made at Pilar in 1911 during the first visit of the *Carnegie*, and again by Observer H. P. Johnston in 1913, so that the correlation of the Argentine magnetic work with that of the Department has now been controlled three times.

On account of the war it was considered best to detain the *Carnegie* at Buenos Aires. The ocean work of Cruise IV was brought to a conclusion and members of the party were assigned to other duties. Observer Jones was instructed to proceed to Lima, Peru, where he joined Mr. Fleming's party and was assigned to land work (see page 268). Observers A. D. Power and L. L. Tanguy were assigned to land work in Argentina, viz, to reoccupy certain magnetic stations established by the Argentine Government. Mr. George O. Wiggin, director of the Argentine Meteorological Service, assisted the *Carnegie* party in many ways and greatly facilitated the work in Argentina. Through his efforts passes over all the railway and steamship lines were given to each member of the party, and free entry for all the scientific instruments was granted by the customs department. At the solicitation of the American ambassador at Buenos Aires, the Argentine government extended port facilities, wharfage, etc., freely to the *Carnegie* during her stay in port. The Department takes this opportunity to express its thanks to the government and people of Argentina for the many courtesies extended.

On May 29, 1917, Capt. J. P. Ault, having been in command of the *Carnegie* for three years, was instructed by cable to return to Washington via Valparaiso for conference and assignment to shore duty. After completing all arrangements for turning over the command of the *Carnegie* to Dr. H. M. W. Edmonds, who had been second in command for three years, Captain Ault left Buenos Aires on June 10 for Washington, where he arrived on July 25.

At the close of the fiscal year plans were being completed for the *Carnegie* to return to the Pacific Ocean via Cape Horn or the Straits

of Magellan. Observer J. M. McFadden left Washington the middle of September to report for duty on the *Carnegie* at Buenos Aires.

The ship's personnel during November 1916 to October 1917, was as follows: J. P. Ault, magnetician and in command of vessel (to June 1, 1917); Dr. H. M. W. Edmonds, magnetician and surgeon and second in command (to June 1, 1917), in command (from June 1, 1917); A. D. Power, B. Jones, L. L. Tanguy, and J. M. McFadden (from October 1917), observers; N. Meisenhelter, stenographer-recorder; A. Beech, first watch officer; M. G. R. Savary, engineer; L. Larsen and A. Erickson, second and third watch officers, respectively; C. Heckendorn, mechanic; 8 seamen, 2 cooks, and 2 cabin boys; the complete personnel at any time consisting of 23 persons.

For an account of the atmospheric-electric work aboard the *Carnegie* see pages 253 and 254.

Table 2 contains the preliminary results of Ocean Magnetic Observations on the *Carnegie* from San Francisco to Easter Island and Buenos Aires, November 1916 to March 1917. This table supplements the preliminary results for Cruise IV of the *Carnegie*, March 1915 to September 1916, published in Volume III (Researches of the Department of Terrestrial Magnetism), pages 286–293. Since Cruise IV was completed at Buenos Aires on March 2, 1917, the results, sufficiently accurate for all practical purposes, are now in print for the entire cruise. While these preliminary results are subject to future revision, it is not probable that there will be many cases in which the values of declination, or of inclination, will be changed by more than $0^\circ.1$, and the values of the horizontal intensity by more than 0.001 C. G. S.

The chart corrections for the principal charts in use are likewise given in Table 2. Before deriving them, the values of the magnetic elements as scaled from the various charts were referred to the date of the *Carnegie* observations with the aid of whatever annual-change data were given on the charts; the chart corrections as tabulated are thus affected in part by errors in the published annual changes. On the average, the declination corrections are smallest for the very recent British Admiralty charts (1917), in the construction of which all the values of the *Galilee* and the *Carnegie* contained in Volume III were available.

TABLE 2.—*Preliminary results of ocean magnetic observations on the Carnegie from San Francisco to Easter Island and Buenos Aires, November 1916 to March 1917.*[1]

Observers: J. P. Ault, commanding the *Carnegie:* H. M. W. Edmonds, B. Jones, A. D. Power, L. L. Tanguy, and N. Meisenhelter.

Date.	Latitude.	Long. E. of Gr.	Carnegie values.			Chart corrections.					
			Decl'n.	Incl'n.	Hor. int.	Brit.[2]	Ger.[2]	U. S.[2]	B.[3]	G.[3]	U.[3]
1916	° ′	° ′	°	°	c.g.s.	°	°	°	*	*	*
Nov. 2	36 06 N	236 41	17.1 E	......	...	0.5W	0.1 E	0.2W	....	....	....
2	35 46 N	236 45	......	60.1 N	.259	0.4 S	0.4 N	.....	− 3	−13	+ 2
2	35 42 N	236 46	17.1 E	......	...	0.4W	0.3 E	0.0	....	....	....
3	35 22 N	236 14	16.9 E	......	...	0.5W	0.4 E	0.0	....	....	....
3	35 10 N	236 05	......	59.4 N	.261	0.6 S	0.6 N	.....	− 3	−13	+ 2
3	34 59 N	236 07	16.7 E	......	...	0.5W	0.3 E	0.1W	....	....	....
4	34 24 N	236 17	16.2 E	......	...	0.7W	0.1 E	0.3W	....	....	....
4	33 56 N	236 36	......	58.3 N	.268	0.1 S	0.9 N	.....	− 2	−14	+ 4
5	32 14 N	237 03	15.5 E	......	...	0.3W	0.3 E	0.2W	....	....	....
5	31 20 N	237 10	......	55.9 N	.280	0.3 N	0.9 N	.....	− 2	−13	+ 5
5	31 04 N	237 10	15.1 E	......	...	0.2W	0.5 E	0.3W	....	....	....
6	29 45 N	238 05	14.2 E	......	...	0.5W	0.1 E	0.7W	....	....	....
6	28 58 N	238 33	......	53.6 N	.287	0.9 N	0.7 N	.....	− 4	−14	+ 4
6	28 46 N	238 40	14.4 E	......	...	0.1 E	0.7 E	0.1 E	....	....	....
7	27 16 N	239 43	13.4 E	......	...	0.3W	0.4 E	0.1W	....	....	....
7	26 25 N	240 11	......	50.8 N	.298	1.0 N	0.6 N	.....	− 3	−12	+ 5
7	26 12 N	240 18	12.9 E	......	...	0.4W	0.3 E	0.2W	....	....	....
8	24 20 N	241 25	12.4 E	......	...	0.2W	0.6 E	0.2W	....	....	....
8	23 21 N	241 57	......	47.5 N	.309	0.5 N	1.5 N	.....	− 2	−12	+ 5
8	23 06 N	242 05	11.7 E	......	...	0.4W	0.4 E	0.6W	....	....	....
9	21 19 N	243 08	11.1 E	......	...	0.4W	0.4 E	0.6W	....	....	....
9	20 53 N	243 19	......	44.5 N	.316	0.3 N	1.3 N	.....	− 4	−10	+ 3
9	20 47 N	243 22	10.7 E	......	...	0.6W	0.2 E	0.8W	....	....	....
10	20 16 N	243 41	10.6 E	......	...	0.5W	0.2 E	0.8W	....	....	....
10	19 59 N	243 49	......	43.0 N	.321	0.4 S	0.8 N	.....	− 2	− 7	+ 5
10	19 55 N	243 50	10.9 E	......	...	0.1W	0.6 E	0.4W	....	....	....
11	19 36 N	243 51	10.8 E	......	...	0.1W	0.6 E	0.3W	....	....	....
11	19 28 N	243 54	......	42.3 N	.322	0.4 S	1.1 N	.....	− 2	− 7	+ 5
11	19 26 N	243 55	10.7 E	......	...	0.1W	0.6 E	0.4W	....	....	....
12	19 00 N	244 15	10.4 E	......	...	0.2W	0.4 E	0.6W	....	....	....
12	18 31 N	244 26	......	41.1 N	.325	0.6 S	0.9 N	.....	− 1	− 7	+ 5
12	18 23 N	244 26	10.1 E	......	...	0.4W	0.1 E	0.8W	....	....	....
13	17 02 N	244 38	10.2 E	......	...	0.1 E	0.6 E	0.3W	....	....	....
13	16 33 N	244 39	......	38.1 N	.330	0.5 S	1.7 N	.....	0	− 6	+ 3
13	16 22 N	244 40	10.0 E	......	...	0.0	0.6 E	0.3W	....	....	....
14	14 47 N	244 56	......	35.2 N	.334	0.5 S	1.6 N	.....	+ 3	− 7	+ 1
14	14 46 N	244 56	9.6 E	......	...	0.1W	0.4 E	0.6W	....	....	....
14	14 39 N	244 56	9.6 E	......	...	0.1W	0.4 E	0.5W	....	....	....
15	14 17 N	244 56	9.6 E	......	...	0.1W	0.4 E	0.3W	....	....	....
15	14 10 N	244 56	......	34.3 N	.335	0.7 S	2.0 N	.....	+ 3	− 8	+ 1

[1]For previous ocean results (1905–1916), see Carnegie Inst. Wash. Publication 175 (Vol. III), pp. 97–104, 261–295.

[2]Declination and inclination charts used for comparison: British Admiralty Charts Nos. 3775, 3776, and 3777 for 1917, and No. 3598 for 1907; Reich's Marine-Amt Charts, Tit. XIV, No. 2, for 1910, Tit. XIV, No. 2*a*, for 1905; U. S. Hydrographic Office Chart No. 2406 for 1915.

[3]Horizontal-intensity charts used for comparison: British Admiralty Chart No. 3603 for 1907; Reich's Marine-Amt Chart, Tit. XIV, No. 2*b* for 1905; U. S. Hydrographic Office Chart No. 1701 for 1900.

*Units of third decimal C. G. S.

TABLE 2.—*Preliminary results of ocean magnetic observations, November 1916 to March 1917*—Continued.

Date.	Latitude.	Long. E. of Gr.	Carnegie values.			Chart corrections.					
			Decl'n.	Incl'n.	Hor. int.	Brit.	Ger.	U. S.	B.	G.	U.
1916	° ′	° ′	°	°	*c.g.s.*	°	°	°	*	*	*
Nov. 15	14 01 N	244 57	9.5 E	......	...	0.1 W	0.3 E	0.3 W	....	....	....
16	12 54 N	244 52	9.3 E	......	...	0.2 W	0.2 E	0.2 W	....	....	....
16	12 02 N	245 01	......	30.6 N	.338	1.0 S	1.9 N	.....	+ 5	−14	−12
16	11 45 N	245 06	9.2 E	......	...	0.1 W	0.3 E	0.0	....	....	....
17	10 09 N	245 57	9.0 E	......	...	0.2 W	0.2 E	0.0	....	....	....
17	9 21 N	246 31	......	26.1 N	.340	0.9 S	3.0 N	.....	+ 6	−20	−10
17	9 10 N	246 37	8.7 E	......	...	0.3 W	0.1 E	0.3 W	....	....	....
18	8 48 N	246 39	8.9 E	......	...	0.1 W	0.3 E	0.0	....	....	....
18	8 54 N	246 26	......	25.3 N	.342	0.7 S	3.1 N	.....	+ 8	−18	− 8
18	8 54 N	246 30	8.9 E	......	...	0.1 W	0.3 E	0.1 W	....	....	....
19	8 53 N	247 22	......	25.6 N	.341	0.6 S	3.2 N	.....	+ 7	−19	−11
19	8 48 N	247 30	8.9 E	......	...	0.1 W	0.4 E	0.0	....	....	....
20	8 00 N	248 28	8.8 E	......	...	0.2 W	0.4 E	0.0	....	....	....
20	7 46 N	248 39	......	23.7 N	.342	0.8 S	3.5 N	.....	+ 7	−18	−15
20	7 42 N	248 43	8.8 E	......	...	0.2 W	0.4 E	0.0	....	....	....
21	7 42 N	248 55	8.8 E	......	...	0.2 W	0.4 E	0.0	....	....	....
21	7 34 N	249 46	......	23.6 N	.342	0.9 S	3.7 N	.....	+ 7	−18	−18
22	7 32 N	250 22	8.9 E	......	...	0.1 W	0.7 E	0.1 W	....	....	....
22	7 28 N	250 46	......	23.6 N	.343	0.9 S	3.6 N	.....	+ 8	−17	−17
23	7 15 N	251 05	8.9 E	......	...	0.1 W	0.7 E	0.1 W	....	....	....
23	7 10 N	251 15	......	23.2 N	.342	1.0 S	3.6 N	.....	+ 7	−18	−18
24	7 06 N	250 36	9.0 E	......	...	0.0	0.8 E	0.0	....	....	....
24	7 00 N	251 16	......	23.1 N	.342	0.5 S	4.1 N	.....	+ 7	−18	−18
25	6 52 N	252 49	8.7 E	......	...	0.3 W	0.7 E	0.3 W	....	....	....
25	6 52 N	253 13	......	23.1 N	.343	0.5 S	3.7 N	.....	+ 8	−17	−17
26	6 21 N	253 31	9.1 E	......	...	0.1 E	1.1 E	0.1 E	....	....	....
26	6 11 N	253 15	......	21.8 N	.342	0.4 S	3.6 N	.....	+ 7	−18	−18
27	5 37 N	252 19	9.0 E	......	...	0.0	0.9 E	0.0	....	....	....
27	5 22 N	251 41	......	19.9 N	.343	0.7 S	3.9 N	.....	+ 8	−17	−17
28	5 07 N	249 52	8.8 E	......	...	0.1 W	0.6 E	0.1 W	....	....	....
28	5 04 N	249 06	......	18.7 N	.343	1.1 S	3.8 N	.....	+ 8	−17	−17
28	4 56 N	248 27	8.7 E	......	...	0.1 W	0.3 E	0.1 W	....	....	....
29	4 28 N	247 37	8.8 E	......	...	0.0	0.4 E	0.0	....	....	....
29	3 52 N	246 46	......	16.1 N	.340	0.8 S	3.9 N	.....	+ 4	−20	−20
29	3 43 N	246 30	8.8 E	......	...	0.0	0.3 E	0.1 E	....	....	....
30	2 25 N	244 35	8.4 E	......	...	0.3 W	0.2 W	0.3 W	....	....	....
30	1 40 N	243 19	......	10.8 N	.339	1.8 S	3.1 N	.....	+ 3	−18	−16
30	1 22 N	242 56	8.6 E	......	...	0.0	0.0	0.1 W	....	....	....
Dec. 1	0 06 N	241 39	8.4 E	......	...	0.2 W	0.1 W	0.3 W	....	....	....
1	0 27 S	241 24	......	6.3 N	.338	2.2 S	2.6 N	.....	+ 2	−14	−15
1	0 42 S	241 16	8.5 E	......	...	0.2 W	0.0	0.2 W	....	....	....
2	1 19 S	240 53	8.3 E	......	...	0.4 W	0.2 W	0.5 W	....	....	....
2	1 29 S	240 41	......	3.9 N	.338	3.1 S	1.9 N	.....	+ 2	−12	−13
2	1 40 S	240 36	8.4 E	......	...	0.3 W	0.1 W	0.4 W	....	....	....
3	2 05 S	240 08	8.6 E	......	...	0.1 W	0.0	0.2 W	....	....	....
3	2 29 S	239 54	......	1.9 N	.337	3.3 S	2.1 N	.....	0	−11	−12
3	2 44 S	239 48	8.5 E	......	...	0.3 W	0.2 W	0.4 W	....	....	....
4	3 55 S	239 16	8.5 E	......	...	0.3 W	0.3 W	0.4 W	....	....	....
4	4 41 S	238 55	......	2.7 S	.335	4.5 S	1.9 N	.....	− 1	− 9	− 9
4	4 57 S	238 43	8.7 E	......	...	0.2 W	0.1 W	0.3 W	....	....	....
5	6 20 S	237 27	8.7 E	......	...	0.2 W	0.1 W	0.3 W	....	....	....
5	7 08 S	236 42	......	7.6 S	.333	5.0 S	1.7 N	.....	− 2	− 6	− 6
5	7 25 S	236 26	8.9 E	......	...	0.1 W	0.0	0.2 W	....	....	....
6	9 02 S	235 12	9.0 E	......	...	0.2 W	0.0	0.3 W	....	....	....

*Units of third decimal C. G. S.

TABLE 2.—*Preliminary results of ocean magnetic observations, November 1916 to March 1917*—Continued.

Date.	Latitude.	Long. E. of Gr.	Carnegie values.			Chart corrections.					
			Decl'n.	Incl'n.	Hor. int.	Brit.	Ger.	U. S.	B.	G.	U.
1916	° ′	° ′	°	°	*c.g.s.*	°	°	°	*	*	*
Dec. 6	10 02 S	234 54	......	13.6 S	.332	6.4 S	1.7 N	.....	− 1	− 3	− 3
6	10 21 S	234 48	9.3 E	......	...	0.0	0.2 E	0.1 W	....	....	....
7	12 00 S	234 34	9.4 E	......	...	0.1 W	0.1 E	0.3 W	....	....	....
7	12 54 S	234 26	......	19.0 S	.328	7.0 S	1.2 N	.....	− 4	− 3	− 4
7	13 20 S	234 21	9.8 E	......	...	0.1 E	0.3 E	0.0	....	....	....
8	15 11 S	234 09	9.8 E	......	...	0.1 W	0.0	0.3 W	....	....	....
8	16 00 S	234 12	......	24.6 S	.324	6.0 S	1.3 N	.....	− 6	0	− 2
8	16 10 S	234 12	10.0 E	......	...	0.1 W	0.0	0.3 W	....	....	....
9	17 19 S	234 02	10.3 E	......	...	0.1 W	0.1 E	0.2 W	....	....	....
9	18 06 S	233 50	......	28.0 S	.322	5.4 S	1.9 N	.....	− 5	+ 3	0
9	18 26 S	233 45	10.7 E	......	...	0.1 E	0.4 E	0.1 W	....	....	....
10	19 51 S	233 24	10.9 E	......	...	0.1 W	0.4 E	0.2 W	....	....	....
10	20 26 S	233 15	......	31.6 S	.318	4.8 S	2.0 N	.....	− 5	+ 2	+ 1
10	20 38 S	233 14	11.1 E	......	...	0.1 W	0.4 E	0.2 W	....	....	....
11	21 50 S	233 27	11.4 E	......	...	0.1 W	0.4 E	0.2 W	....	....	....
11	22 33 S	233 32	......	34.6 S	.316	4.4 S	2.4 N	.....	− 2	+ 3	+ 4
11	22 51 S	233 35	11.5 E	......	...	0.3 W	0.2 E	0.3 W	....	....	....
12	24 14 S	233 56	11.9 E	......	...	0.2 W	0.2 E	0.2 W	....	....	....
12	25 05 S	234 11	......	38.3 S	.312	5.4 S	2.4 N	.....	− 1	+ 6	+ 7
12	25 20 S	234 24	12.5 E	......	...	0.1 E	0.4 E	0.1 E	....	....	....
13	26 13 S	235 13	12.4 E	......	...	0.3 W	0.1 W	0.3 W	....	..	....
13	26 36 S	235 42	......	39.7 S	.308	5.7 S	2.6 N	.....	0	+ 5	+ 7
13	26 42 S	235 48	12.2 E	......	...	0.7 W	0.5 W	0.6 W	....	....	....
14	27 11 S	236 28	12.8 E	......	...	0.2 W	0.2 W	0.1 W	....	....	....
14	27 25 S	236 48	......	40.9 S	.306	6.3 S	2.3 N	.....	− 1	+ 6	+ 7
14	27 28 S	236 53	12.8 E	......	...	0.3 W	0.2 W	0.3 W	....	....	....
15	27 45 S	237 14	13.4 E	......	...	0.2 E	0.2 E	0.2 E	....	....	....
15	27 56 S	237 31	......	41.4 S	.304	6.4 S	2.4 N	.....	− 2	+ 5	+ 7
15	28 01 S	237 37	13.2 E	......	...	0.1 W	0.0	0.1 W	....	....	....
16	28 40 S	238 13	13.6 E	......	...	0.1 E	0.1 E	0.1 E	....	....	....
16	29 06 S	238 43	......	42.7 S	.302	6.7 S	2.8 N	.....	− 1	+ 6	+ 8
16	29 15 S	238 54	13.5 E	......	...	0.3 W	0.4 W	0.2 W	....	....	....
17	29 56 S	239 42	13.8 E	......	...	0.2 W	0.3 W	0.1 W	....	....	....
17	30 31 S	240 42	......	44.1 S	.300	7.3 S	2.5 N	.....	+ 1	+ 9	+11
17	30 32 S	241 16	14.8 E	......	...	0.4 E	0.1 E	0.4 E	....	....	....
18	31 35 S	242 18	14.8 E	......	...	0.0	0.5 W	0.1 W	....	....	....
18	31 45 S	243 06	......	45.0 S	.296	7.2 S	2.2 N	.....	− 1	+ 9	+10
18	31 39 S	243 24	14.8 E	......	...	0.1 W	0.7 W	0.4 W	....	....	....
18	31 42 S	243 37	15.4 E	......	...	0.4 E	0.2 W	0.1 E	....	....	....
19	31 59 S	244 43	15.7 E	......	...	0.5 E	0.2 W	0.2 E	....	....	....
19	32 16 S	245 39	......	45.2 S	.294	7.2 S	2.4 N	.....	− 2	+ 9	+10
19	32 24 S	246 00	15.2 E	......	...	0.3 W	1.1 W	0.7 W	....	....	....
20	32 33 S	247 05	15.2 E	......	...	0.5 W	1.3 W	1.0 W	....	....	....
20	32 12 S	248 43	......	44.5 S	.292	7.2 S	2.6 N	.....	− 4	+ 7	+ 8
20	32 06 S	248 58	16.1 E	......	...	0.3 E	0.8 W	0.2 W	....	....	....
21	31 18 S	250 29	15.6 E	......	...	0.0	1.4 W	0.6 W	....	....	....
21	30 55 S	251 06	......	43.2 S	.293	7.9 S	2.0 N	.....	− 4	+ 6	+ 6
21	30 46 S	251 14	16.8 E	......	...	1.3 E	0.1 W	0.8 E	....	....	....
22	30 40 S	251 08	16.4 E	......	...	0.9 E	0.4 W	0.5 E	....	....	....
22	30 36 S	251 11	......	41.9 S	.296	6.9 S	3.0 N	.....	− 1	+ 8	+ 8
22	30 42 S	251 20	16.9 E	......	...	1.4 E	0.0	0.9 E	....	....	....
23	30 48 S	251 26	15.6 E	......	...	0.1 E	1.1 W	0.3 W	....	....	....
23	30 05 S	251 25	......	41.2 S	.295	6.6 S	3.2 N	.....	− 3	+ 7	+ 6
23	29 42 S	251 24	15.2 E	......	...	0.0	1.3 W	0.5 W	....	....	....
24	27 57 S	251 20	14.5 E	......	...	0.0	1.4 W	0.6 W	....	....	....

*Units of third decimal C. G. S.

TABLE 2.—*Preliminary results of ocean magnetic observations, November 1916 to March 1917*—Continued.

Date.	Latitude.	Long. E. of Gr.	Carnegie values.			Chart corrections.					
			Decl'n.	Incl'n.	Hor. int.	Brit.	Ger.	U. S.	B.	G.	U.
1917	° ′	° ′	°	°	*c.g.s.*	°	°	°	*	*	*
Jan. 2	27 08 S	250 34	12.6 E[1]	......	...	1.6W	2.9W	2.1W	....	....	....
2	26 38 S	250 12	......	37.6 S	.299	6.3 S	2.4 N	.....	− 5	+ 1	+ 2
2	26 29 S	250 07	13.6 E	......	...	0.3W	1.6W	0.8W	....	....	....
3	25 05 S	249 17	13.0 E	......	...	0.4W	1.6W	0.8W	....	....	....
3	23 58 S	248 58	......	34.5 S	.304	6.1 S	1.9 N	.....	− 4	− 1	0
3	23 35 S	248 55	12.5 E	......	...	0.4W	1.4W	0.6W	....	....	....
4	22 07 S	248 45	12.3 E	......	...	0.2W	1.3W	0.0	....	....	....
4	21 05 S	248 52	......	30.3 S	.306	6.1 S	2.0 N	.....	− 8	− 6	− 6
4	20 41 S	248 51	12.3 E	......	...	0.2 E	0.7W	0.4 E	....	....	....
5	18 50 S	248 34	11.3 E	......	...	0.3W	1.2W	0.1W	....	....	....
5	17 54 S	248 40	......	25.0 S	.312	6.2 S	1.4 N	.....	− 7	− 6	− 8
5	17 28 S	248 44	11.0 E	......	...	0.3W	1.0W	0.2W	....	....	....
6	15 34 S	248 56	10.4 E	......	...	0.4W	1.0W	0.4W	....	....	....
6	14 45 S	248 51	......	19.6 S	.318	6.8 S	1.9 N	.....	− 9	− 8	− 8
6	14 23 S	248 52	10.9 E	......	...	0.4 E	0.2W	0.4 E	....	....	....
7	12 31 S	248 54	10.0 E	......	...	0.1W	0.6W	0.1W	....	....	....
7	12 29 S	248 23	......	15.7 S	.321	7.0 S	2.0 N	.....	− 9	−10	− 9
7	12 29 S	248 04	10.9 E	......	...	0.9 E	0.4 E	0.8 E	....	....	....
8	12 30 S	246 37	9.7 E	......	...	0.3W	0.6W	0.3W	....	....	....
8	12 30 S	245 31	......	16.3 S	.322	7.2 S	1.8 N	.....	− 8	− 9	− 9
8	12 31 S	245 08	9.9 E	......	...	0.0	0.3W	0.1W	....	....	....
9	12 33 S	243 34	9.6 E	......	...	0.2W	0.4W	0.4W	....	....	....
9	12 34 S	242 38	......	17.0 S	.322	7.4 S	1.7 N	.....	− 9	− 9	− 9
9	12 35 S	242 13	9.7 E	......	...	0.1W	0.3W	0.2W	....	....	....
10	12 36 S	240 26	9.6 E	......	...	0.1W	0.3W	0.3W	....	....	....
10	12 36 S	239 24	......	17.8 S	.325	7.2 S	1.4 N	.....	− 7	− 6	− 6
10	12 36 S	239 05	9.5 E	......	...	0.2W	0.2W	0.3W	....	....	....
11	12 40 S	237 23	9.3 E	......	...	0.3W	0.3W	0.5W	....	....	....
11	12 55 S	236 27	......	18.4 S	.325	6.7 S	1.8 N	.....	− 8	− 6	− 6
11	13 10 S	236 12	10.0 E	......	...	0.3 E	0.3 E	0.2 E	....	....	....
12	14 06 S	234 54	9.9 E	......	...	0.1 E	0.2 E	0.0	....	....	....
12	14 40 S	234 16	......	22.0 S	.325	6.0 S	1.3 N	.....	− 6	− 2	− 3
12	14 53 S	234 03	10.2 E	......	...	0.3 E	0.5 E	0.2 E	....	....	....
13	15 48 S	233 06	10.0 E	......	...	0.0	0.0	0.1W	....	....	....
13	16 08 S	232 38	......	24.9 S	.324	5.6 S	1.5 N	.....	− 6	0	− 2
13	16 21 S	232 23	10.3 E	......	...	0.2 E	0.3 E	0.1 E	....	....	....
14	16 59 S	231 46	10.7 E	......	...	0.5 E	0.6 E	0.3 E	....	....	....
14	17 42 S	231 09	......	27.8 S	.322	5.3 S	1.4 N	.....	− 7	+ 1	− 1
15	19 35 S	230 06	10.8 E	......	...	0.0	0.4 E	0.2W	....	....	....
15	19 36 S	230 02	......	30.8 S	.321	4.2 S	1.9 N	.....	− 4	+ 3	+ 1
16	19 38 S	229 49	10.7 E	......	...	0.1W	0.3 E	0.3W	....	....	....
16	19 42 S	229 46	......	31.2 S	.320	4.2 S	1.7 N	.....	− 5	− 3	0
16	19 42 S	229 45	10.7 E	......	...	0.1W	0.3 E	0.3W	....	....	....
17	19 58 S	229 18	11.2 E	......	...	0.3 E	0.8 E	0.1 E	....	....	....
17	20 18 S	228 54	......	32.1 S	.320	4.0 S	1.9 N	.....	− 4	+ 3	0
18	21 21 S	227 31	11.5 E	......	...	0.3 E	1.0 E	0.3 E	....	....	....
18	21 48 S	226 48	......	34.9 S	.320	4.2 S	1.7 N	.....	− 2	+ 5	+ 4
18	21 55 S	226 29	11.6 E	......	...	0.3 E	1.1 E	0.1 E	....	....	....
19	22 53 S	225 18	11.7 E	......	...	0.2 E	1.0 E	0.0	....	....	....
19	23 55 S	224 58	......	37.9 S	.315	4.8 S	1.6 N	.....	− 3	+ 3	+ 2
19	24 24 S	224 51	12.0 E	......	...	0.1 E	1.1 E	0.0	....	....	....
20	26 08 S	223 56	12.4 E	......	...	0.1 E	1.2 E	0.0	....	....	....
20	27 01 S	223 14	......	42.8 S	.311	6.0 S	1.4 N	.....	+ 1	+ 6	+ 6
20	27 22 S	223 01	12.8 E	......	...	0.2 E	1.4 E	0.0	....	....	....

*Units of third decimal C. G. S. [1]Local disturbance.

TABLE 2.—*Preliminary results of ocean magnetic observations, November 1916 to March 1917*—Continued.

Date.	Latitude.	Long. E. of Gr.	Carnegie values.			Chart corrections.					
			Decl'n.	Incl'n.	Hor. int.	Brit.	Ger.	U. S.	B.	G.	U.
1917	° ′	° ′	°	°	*c.g.s.*	°	°	°	*	*	*
Jan. 21	28 53 S	221 43	12.8 E	......	...	0.2 W	1.1 E	0.3 W	....	....	....
21	29 53 S	220 53	......	46.5 S	.305	6.5 S	1.1 N	.....	+ 3	+ 6	+ 6
21	30 20 S	220 37	13.6 E	......	...	0.3 E	1.6 E	0.1 E	....	....	....
22	31 54 S	220 29	13.8 E	......	...	0.0	1.4 E	0.1 W	....	....	....
22	32 31 S	220 19	......	49.6 S	.299	6.4 S	0.8 N	.....	+ 6	+ 8	+ 8
23	35 05 S	219 54	......	52.6 S	.290	5.8 S	0.5 N	.....	+ 6	+ 9	+ 8
23	35 19 S	219 46	14.7 E	......	...	0.1 W	1.4 E	0.0	....	....	....
24	37 15 S	218 15	14.5 E	......	...	0.9 W	0.7 E	0.6 W	....	....	....
24	37 22 S	218 00	......	55.2 S	.283	5.7 S	0.4 N	.....	+ 6	+10	+ 9
25	37 31 S	217 16	15.2 E	......	...	0.2 W	1.4 E	0.1 E	....	....	....
25	37 37 S	217 06	......	55.6 S	.281	5.4 S	0.1 N	.....	+ 6	+ 8	+ 8
26	37 47 S	216 09	......	55.8 S	.282	5.1 S	0.2 N	.....	+ 8	+10	+ 9
27	37 52 S	215 23	15.3 E	......	...	0.2 W	1.5 E	0.0	....	....	....
27	37 53 S	215 48	......	55.9 S	.280	5.0 S	0.2 N	.....	+ 7	+ 8	+ 7
27	37 54 S	216 06	15.4 E	......	...	0.1 W	1.6 E	0.1 E	....	....	....
28	37 47 S	216 54	15.4 E	......	...	0.1 W	1.6 E	0.1 E	....	....	....
28	37 45 S	217 37	......	55.6 S	.282	5.3 S	0.2 N	.....	+ 7	+10	+ 9
28	37 36 S	218 13	15.4 E	......	...	0.1 W	1.5 E	0.1 E	....	....	....
29	38 08 S	219 20	15.6 E	......	...	0.1 W	1.3 E	0.2 E	....	....	....
29	38 29 S	220 32	......	55.4 S	.281	4.7 S	0.8 N	.....	+ 6	+12	+12
29	38 31 S	220 48	15.8 E	......	...	0.0	1.3 E	0.2 E	....	....	....
30	38 34 S	221 37	16.0 E	......	...	0.1 E	1.5 E	0.3 E	....	....	....
30	38 31 S	221 44	......	55.6 S	.281	5.4 S	0.6 N	.....	+ 5	+12	+12
30	38 31 S	221 46	16.2 E	......	...	0.3 E	1.7 E	0.6 E	....	....	....
31	38 59 S	222 10	16.0 E	......	...	0.0	1.4 E	0.1 E	....	....	....
31	39 47 S	222 25	......	56.9 S	.275	5.1 S	0.3 N	.....	+ 1	+11	+10
31	40 05 S	222 25	16.6 E	......	...	0.2 E	1.5 E	0.0	....	....	....
Feb. 1	41 21 S	222 11	17.0 E	......	...	0.2 E	1.5 E	0.1 W	....	....	....
1	42 16 S	221 53	......	59.1 S	.268	4.1 S	0.3 N	.....	+ 1	+13	+12
1	42 31 S	221 44	17.4 E	......	...	0.2 E	1.6 E	0.1 W	....	....	....
2	43 41 S	221 17	18.0 E	......	...	0.4 E	1.8 E	0.1 E	....	....	....
2	43 36 S	221 45	......	60.3 S	.263	3.5 S	0.2 N	.....	− 1	+12	+11
3	42 58 S	224 40	17.4 E	......	...	0.4 W	1.0 E	0.4 W	....	....	....
3	42 27 S	226 03	......	58.7 S	.270	4.8 S	0.5 N	.....	− 1	+15	+14
3	42 21 S	226 17	17.5 E	......	...	0.1 E	1.2 E	0.2 W	....	....	....
4	42 49 S	228 00	18.4 E	......	...	0.7 E	1.8 E	0.5 E	....	....	....
4	43 24 S	229 04	......	58.9 S	.270	4.3 S	0.8 N	.....	− 2	+17	+18
4	43 41 S	229 35	18.5 E	......	...	0.4 E	1.2 E	0.1 E	....	....	....
5	44 53 S	231 49	19.5 E	......	...	0.6 E	1.3 E	0.4 E	....	....	....
5	45 24 S	232 51	......	59.9 S	.264	3.6 S	0.8 N	.....	− 6	+15	+16
5	45 42 S	233 29	20.2 E	......	...	0.6 E	1.4 E	0.5 E	....	....	....
6	46 24 S	235 19	20.6 E	......	...	0.6 E	1.1 E	0.2 E	....	....	....
6	46 28 S	237 16	......	60.2 S	.262	3.6 S	0.8 N	.....	−10	+14	+16
6	46 27 S	237 57	21.5 E	......	...	1.2 E	1.3 E	0.6 E	....	....	....
7	46 46 S	240 58	21.7 E	......	...	0.7 E	0.8 E	0.0	....	....	....
7	47 08 S	241 44	......	59.9 S	.262	3.9 S	0.9 N	.....	−12	+13	+15
7	47 16 S	242 00	21.7 E	......	...	0.3 E	0.3 E	0.6 W	....	....	....
8	49 12 S	244 29	......	61.0 S	.259	3.2 S	0.8 N	.....	−14	+13	+14
8	49 30 S	244 54	24.2 E	......	...	1.1 E	1.0 E	0.0	....	....	....
9	52 14 S	248 13	......	62.1 S	.253	1.7 S	1.1 N	.....	−19	+12	+ 9
10	54 10 S	252 45	......	62.3 S	.252	0.8 S	1.4 N	.....	−20	+11	+ 4
11	54 33 S	257 14	27.6 E	......	...	0.1 W	1.2 W	0.8 W	....	....	....
11	54 41 S	258 40	......	61.0 S	.257	0.5 S	1.6 N	.....	−19	+ 8	+ 1
11	54 43 S	259 01	29.1 E	......	...	1.2 E	0.0	0.8 E	....	....	....
11	54 46 S	259 31	28.1 E	......	...	0.2 E	1.1 W	0.3 W	....	....	....

*Units of third decimal C. G. S.

TABLE 2.—*Preliminary results of ocean magnetic observations, November 1916 to March 1917*—Continued.

Date.	Latitude.	Long. E. of Gr.	Carnegie values.			Chart corrections.					
			Decl'n.	Incl'n.	Hor. int.	Brit.	Ger.	U. S.	B.	G.	U.
1917	° ′	° ′	°	°	*c.g.s.*	°	°	°	*	*	*
Feb. 12	55 07 S	263 14	28.0 E	......	...	0.0	1.1W	0.0	....	....	....
12	55 24 S	265 18	......	59.3 S	.262	0.2 N	1.6 N	.....	−17	+ 7	− 2
12	55 28 S	265 47	27.9 E	......	...	0.0	0.9W	0.2 E	....	....	....
12	55 30 S	266 04	28.3 E	......	...	0.4 E	0.3W	0.6 E	....	....	....
13	56 00 S	269 44	27.4 E	......	...	0.2 E	0.4W	0.4 E	....	....	....
13	56 16 S	272 08	......	57.7 S	.264	1.0 N	1.4 N	.....	−14	+ 1	− 6
13	56 20 S	272 39	26.7 E	......	...	0.3 E	0.3W	0.4 E	....	....	....
14	56 43 S	275 48	25.6 E	......	...	0.1 E	0.4W	0.1W	....	....	....
14	56 56 S	277 48	......	56.5 S	.267	1.3 N	1.0 N	.....	−10	− 1	− 8
15	57 34 S	282 49	22.8 E	......	...	0.1W	0.4W	0.5W	....	....	....
15	57 34 S	284 02	......	55.3 S	.267	1.2 N	0.8 N	.....	− 9	− 6	− 9
15	57 31 S	284 29	22.4 E	......	...	0.4 E	0.0	0.0	....	....	....
15	57 28 S	284 52	21.8 E	......	...	0.0	0.2W	0.4W	....	....	....
16	56 58 S	288 26	20.5 E	......	...	0.6 E	0.9 E	0.5 E	....	....	....
16	56 54 S	288 50	19.2 E	......	...	0.5W	0.1W	0.6W	....	....	....
16	56 52 S	289 07	19.9 E	......	...	0.4 E	0.7 E	0.4 E	....	....	....
16	56 40 S	290 23	......	52.8 S	.268	0.9 N	1.0 N	.....	− 7	−11	− 8
16	56 37 S	290 51	18.5 E	......	...	0.1 E	0.2 E	0.1 E	....	....	....
16	56 35 S	291 18	18.3 E	......	...	0.2 E	0.3 E	0.3 E	....	....	....
17	56 05 S	293 34	17.6 E	......	...	0.9 E	1.1 E	1.1 E	....	....	....
17	55 53 S	295 07	......	51.4 S	.268	0.5 N	0.8 N	.....	− 6	−12	− 7
17	55 50 S	294 18	16.5 E	......	...	0.2 E	0.7 E	0.4 E	....	....	....
17	55 37 S	294 53	16.0 E	......	...	0.2 E	0.5 E	0.2 E	....	....	....
18	55 18 S	295 47	15.2 E	......	...	0.0	0.3 E	0.2 E	....	....	....
18	55 03 S	295 51	......	50.1 S	.267	0.7 N	1.0 N	.....	− 6	−13	− 7
19	53 34 S	296 54	14.1 E	......	...	0.0	0.4 E	0.3 E	....	....	....
19	53 28 S	296 54	......	48.7 S	.265	0.4 N	0.6 N	.....	− 7	−15	− 9
20	52 26 S	295 42	14.4 E	......	...	0.1W	0.1 E	0.3 E	....	....	....
20	52 12 S	296 17	......	47.3 S	.265	0.6 N	0.9 N	.....	− 8	−14	−10
20	52 03 S	296 45	13.5 E	......	...	0.3W	0.2 E	0.1 E	....	....	....
21	50 48 S	298 00	12.4 E	......	...	0.2W	0.1 E	0.3 E	....	....	....
21	49 50 S	298 51	......	44.5 S	.262	0.8 N	0.8 N	.....	−10	−11	−10
21	49 41 S	298 59	11.5 E	......	...	0.1W	0.3 E	0.4 E	....	....	....
22	48 02 S	299 57	10.4 E	......	...	0.1W	0.2 E	0.3 E	....	....	....
22	47 49 S	300 04	......	42.2 S	.260	1.1 N	0.8 N	.....	− 9	− 8	−10
22	47 32 S	300 12	10.0 E	......	...	0.1W	0.2 E	0.1 E	....	....	....
23	46 38 S	300 27	9.6 E	......	...	0.0	0.4 E	0.2 E	....	....	....
23	46 10 S	300 29	......	40.4 S	.259	1.4 N	1.0 N	.....	− 7	− 7	− 9
23	45 59 S	300 30	9.3 E	......	...	0.0	0.2 E	0.2 E	....	....	....
24	45 48 S	300 56	8.9 E	......	...	0.0	0.2 E	0.1 E	....	....	....
24	45 26 S	301 02	......	39.6 S	.257	1.5 N	1.0 N	.....	− 7	− 8	−10
25	43 08 S	301 51	......	37.3 S	.253	1.7 N	0.6 N	.....	− 7	− 9	−12
26	40 30 S	302 46	5.8 E	......	...	0.3W	0.0	0.1 E	....	....	....
26	39 41 S	303 09	......	33.5 S	.248	1.0 N	0.3 N	.....	− 7	− 8	−12
26	39 26 S	303 19	5.2 E	......	...	0.1W	0.3 E	0.1 E	....	....	....
27	38 29 S	303 55	4.3 E	......	...	0.0	0.3 E	0.0	....	....	....
27	38 09 S	304 06	......	31.6 S	.246	1.0 N	0.1 N	.....	− 7	− 7	−12
27	38 06 S	304 08	4.0 E	......	...	0.0	0.2 E	0.1 E	....	....	....
28	37 37 S	304 25	3.5 E	......	...	0.1W	0.1 E	0.1 E	....	....	....
28	36 58 S	304 33	......	30.3 S	.245	0.8 N	0.1 N	.....	− 7	− 6	−11
28	36 43 S	304 32	3.3 E	......	...	0.2 E	0.3 E	0.3 E	....	....	....
Mar. 1	35 28 S	303 49	3.3 E	......	...	0.1 E	0.0	0.1 E	....	....	....
1	35 09 S	303 13	......	28.2 S	.246	0.8 N	0.2 N	.....	− 5	− 5	−10
1	35 08 S	302 58	4.0 E	......	...	0.2 E	0.1 E	0.3 E	....	....	....
2	34 41 S	302 02	4.6 E	......	...	0.0	0.4W	0.1W	....	....	....

*Units of third decimal C. G. S.

LAND WORK.

AFRICA.

After completing a series of observations across French Kongo, from Brazzaville to Libreville, Observer H. E. Sawyer returned to Boma and began preparations for an expedition to the region of Lake Tchad. On November 24, 1916, he left Brazzaville, proceeded up the Kongo River to Bolobo, and from Bolobo up the Ubangi River to Bangui, where he arrived December 21, 1916. At this point a caravan was outfitted for the overland stage to the waters of the Shari River, flowing northward into Lake Tchad. The expedition left Bangui January 20 and arrived at Fort Crampel on the Shari River, February 20, 1917. In this portion of the journey magnetic observations were made at 9 stations. From Fort Crampel Mr. Sawyer proceeded by barge and boat down the river to Fort Lamy, near the south side of Lake Tchad.

The plans for subsequent progress could be only tentatively made in advance of reaching Fort Lamy. It was learned, however, from the French authorities, that conditions would not permit making a contemplated trip from Lake Tchad northward, and accordingly arrangements were made to undertake the route to the east, by way of Abeshr in French Kongo and El Fasher in Darfur, to El Obeid in Anglo-Egyptian Sudan, to Khartum on the Nile. Mr. Sawyer arrived at Fort Lamy April 19, 1917, and proceeded on May 2, partly by launch and partly by means of oxen, to Mao, northeast of Lake Tchad, securing in this region a number of reoccupations of stations of the Tilho Mission which furnish valuable secular-variation data. He left Mao May 28, expecting to arrive at Abeshr about the last of July, and to reach the Nile some time in November.

ASIA.

Dr. C. K. Edmunds, having returned to his duties as President of Canton Christian College, continued the direction of the expedition led by Observer Frederick Brown. After completing a campaign in Manchuria, during which 35 stations were occupied, Mr. Brown left Tientsin for a trip in southwest China, extending through Yunnan province to Bhamo, across the Burma frontier, and returning by a more southerly route by way of Szemao, Mengtsz, and Wuchow to Canton. His route took him by rail to Hankow, where he occupied the C. I. W. repeat station of 1907, and thence by steamer up the Yangtse River to Chungking in Szechwan. He arrived at Chungking November 24, 1916, and continued up the river by launch to Suifu, where he arranged for a trip overland by coolie caravan to Yunnanfu. The latter point was reached January 6, 1917, 19 stations having been occupied, of which 4 (Hankow, Yochow, Ichang, and Yunnanfu) were repeat sta-

tions, the last named having been previously occupied by Dr. Edmunds in connection with his work in Siam and Indo-China in 1911.

Conditions being considered favorable for continuing westward across the Burma frontier to Bhamo, a horse caravan was equipped for the first stage of the journey as far as Talifu. Setting out on January 13, 1917, from Yunnanfu, a two-weeks' journey brought the party to Talifu, 5 stations having been occupied on the way. Here another caravan was organized for the next stage, which proved to be very mountainous and difficult. However, it was successfully covered and Mr. Brown arrived at Tengyueh on February 18, 1917, having made observations at 4 intermediate stations. For the comparatively short journey to Bhamo, about 125 miles, a fresh caravan, consisting of 6 pack animals and 3 mounts, was obtained, by means of which the distance was covered in 7½ days. The Burma frontier was crossed on February 26, 1917, and 3 days later, March 1, the caravan arrived at Bhamo. Observations were made at 2 stations en route, and at Bhamo the station of the India Magnetic Survey was located and reoccupied.

After a brief rest, on March 12 Mr. Brown commenced the return journey, which led southeastward to Szemao, thence to Mengtsz, previously occupied by Dr. Edmunds in 1911, and from there to Poseh, on the Yu Kiang, in Kwangsi Province. A portion of this road was at this time dangerous owing to the presence of lawless bands which had recently been very troublesome. On May 3, 5 days before reaching Mengtsz, the caravan encountered one of these bands, but fortunately escaped without loss. The route from Poseh led down the river by boat through Kwangsi to Wuchow, where the C. I. W. repeat station of 1907 was reoccupied on June 24, 1917, and thence direct to Canton, where Mr. Brown arrived June 26, 1917, having occupied 66 stations, of which 6 were C. I. W. repeat stations, and 1 a station of the India Magnetic Survey.

After having taken a vacation at Canton, Mr. Brown began on August 18, 1917, a short trip through the provinces of Fukien, Kiangsi, and Chekiang. He arrived at Yengpingfu in Fukien on September 15, and proceeded thence northwest to Nanchang in Kiangsi, and back to the coast again to reoccupy Ningpo and Hangchow. In connection with this work it is the intention to secure complete comparisons with the standards of the observatory at Lukiapang, and to reoccupy several of the stations along the coast first established by Dr. Edmunds in 1906.

AUSTRALASIA.

In Australia, Magnetician W. F. Wallis, assisted by Observer W. C. Parkinson, continued the work of examining possible sites for the Western Australian Magnetic Observatory, until the middle of March 1917, when a location fulfilling all the essential conditions was found. This location is about 120 miles north of Perth, about 10 miles west of

Watheroo, Western Australia. Arrangements for the erection of the buildings were completed and the work of construction is well under way.

SOUTH AMERICA.

In the latter part of September 1916, Observers D. M. Wise and Allen Sterling left Washington for the west coast of South America, to investigate several regions with respect to their availability for the location of a magnetic observatory. Stops were made en route at Havana (Cuba), Colon, Tumaco (Colombia), and at 3 stations in Ecuador—Guayaquil, Riobamba, and Quito. At each of these points C. I. W. repeat stations were occupied. In the interval, December 1916 to February 1917, observations were made at repeat stations in the neighborhood of Callao, Lima, Mollendo, and Arequipa. At the last-named place a series of comparisons between the observers' two instrumental outfits was made, after which Mr. Sterling proceeded southward into Chile. In February Mr. J. A. Fleming, Chief of the Observatory Division, assumed charge of the party and took up more in detail the investigation of various possible locations for a magnetic observatory. The regions inland from Callao, Pisco, and Mollendo were examined, in the last case going as far as the region about Lake Titicaca. After a careful study of the conditions in these various regions, a satisfactory location was found near Huancayo, in the Department of Junin. This is about 210 miles by rail from Lima, approximately 60 miles southeast of Oroya, and lying at an altitude of about 11,000 feet above the sea. After making the selection of the site Mr. Fleming returned to Washington, in May 1917. It was decided to postpone to a future time the acquirement of the site and the construction of the observatory buildings.

Mr. Sterling had been detached from the party in February 1917, and proceeded to Chile, going as far south as Coronel, where he arrived April 23, 1917, and reoccupied the station established by the *Carnegie* party in 1912. In all he had occupied 18 stations, 7 of which were C.I.W. repeat stations first established in 1912 and 1913. He had been able to make this trip southward almost entirely by rail, the inland route being possible over the lines of the Longitudinal Railway of Chile. From Coronel he returned to Antofagasta, and proceeded from there to La Paz, Bolivia, by rail, occupying repeat stations at Uyuni and La Paz. Leaving La Paz July 2, 1917, Mr. Sterling went by automobile to Achacache, from there to Sorata, and to Huanay, at the headwaters of the Beni River. From this point his itinerary included a descent of the Beni River, which he successfully accomplished, arriving at Riberalta on September 26. The proposed trip up the Madre do Dios had to be abandoned as impracticable, so Mr. Sterling ascended the Mamoré as far as possible, and finally proceeded down the Madeira to Manaos, Brazil, where he arrived the end of October 1917.

In May, Observer Bradley Jones was detached from the *Carnegie* party, and joined Mr. Wise in Peru (see page 257). After the departure of Mr. Fleming for Washington, Observers Wise and Jones set out together on an expedition to cover the northern portion of the country. Leaving Lima May 16, 1917, they proceeded by rail to Cerro de Pasco, and thence by horses to Huanuco, and from there, partly on horseback and partly on foot, down the Huallaga River to Tingo Maria, where a raft was constructed on which they continued the descent for 3 days, to a point where a canoe could be obtained for proceeding down the river. Their original intention had been to proceed together down this stream to Yurimaguas, where they were to separate, Mr. Wise to take the overland route by way of Moyabamba to Pacasmayo, and Mr. Jones to continue down the Huallaga River to the Marañon, up that river, and west to the coast. This plan was abandoned because information had been received that the route up the Marañon was impracticable. Accordingly, after intercomparing the two instrumental outfits, one outfit was returned to Lima and the two observers proceeded together down the river, the plan now being to reoccupy the C. I. W. station of 1910 at Yurimaguas, and travel thence overland to Moyabamba, Cajamarca, and Pacasmayo. On account of the loss on June 18, 1917, of a part of their outfit in a river accident near Uchiza, they were compelled to abandon the trip further down the river and return by the most direct route to Chimbote, on the coast, where they arrived July 23, 1917. From here the party proceeded to Lima, where Mr. Wise received instructions to return to Washington and Mr. Jones was reassigned to the *Carnegie* at Buenos Aires.

During the *Carnegie's* stay at Buenos Aires the opportunity was afforded of sending out members of the party to reoccupy stations of the Argentine Magnetic Survey. Accordingly Observers A. D. Power and L. L. Tanguy were assigned by Captain Ault to land work, and several expeditions were carried out. The first of these expeditions crossed the country from west to east at about south latitude 39°, beginning at Zapala and proceeding eastward by way of Bahia Blanca to Buenos Aires. This was completed in April and May before the winter season began. The second expedition, completed early in July, crossed the country at about south latitude 33° to 34°, from Mendoza on the west, eastward to Buenos Aires. The third expedition was planned to cover the region from La Quiaca on the north, southward through Cordoba to Buenos Aires. As Mr. Power's services were required on board the *Carnegie* for a few weeks at this time, Mr. Tanguy was instructed to undertake the work of this expedition, which he did beginning about the middle of July.

The land work undertaken by the *Carnegie* party was completed about the middle of October, and comprised the reoccupations of approximately 60 stations. Before beginning the work, comparisons were

secured between the instruments used and those of the magnetic observatory at Pilar, Argentina. A further comparison was made at the close of the work.

MISCELLANEOUS WORK.

In January 1917, Mr. H. R. Schmitt, while temporarily connected with the Department, made a comparison of the inclination standard of the Department with the observatory standard of the United States Coast and Geodetic Survey at Cheltenham, Maryland.

Magnetician H. W. Fisk, in September 1917, established a meridian line on the aviation grounds at Langley Field, Hampton, Virginia, and determined the magnetic elements at this station, as also at the Coast and Geodetic Survey station at Hampton.

In October 1917 Chief Observer W. J. Peters and Magnetician J. P. Ault reoccupied the Coast and Geodetic Survey station at New London, Connecticut, and established new stations about the outer harbor at Ocean Beach, Fisher's Island, Great Gull Island, and Pine Island.

ABSTRACTS OF PUBLICATIONS AND INVESTIGATIONS.

Magnetic declinations observed on the *Carnegie* from Samoa to Guam and San Francisco, June–September, 1916. J. P. Ault. Terr. Mag., vol. 21, 175–176 (Dec. 1916). Washington.

Preliminary results of ocean magnetic observations on the *Carnegie* from San Francisco to Easter Island and Buenos Aires, Nov. 1916—March 1917. J. P. Ault. Terr. Mag., vol. 22, 139–144 (Sept. 1917). Washington.

These two papers by J. P. Ault, in command of the *Carnegie*, give the results of the magnetic observations on the *Carnegie* and the chart corrections as found for the period June 1916 to March 1917. Amplified results will be found in the present annual report (see pages 256–264).

Some results of the ocean scientific work of the Department of Terrestrial Magnetism. [Abstract.] L. A. Bauer. Pop. Astr., vol. 25, 308 (May 1917). Northfield, Minnesota.

This is an abstract of a paper presented before the combined meeting of Section A, American Association for the Advancement of Science, and the American Astronomical Society, held in New York, December 1916. For a fuller account, see Terr. Mag., vol. 22, 129–134 (Sept. 1917).

Remarks on the compass in aeronautics. L. A. Bauer. Proc. Amer. Phil. Soc., vol. 56, 255–257 (June 21, 1917). Philadelphia.

These remarks were made as a contribution to the discussion aroused at the Symposium on Aeronautics of the American Philosophical Society, at Philadelphia, on May 14, 1917.

The recent great progress in aeronautical art and in the construction of ships to navigate the air have called renewed attention to the importance of perfecting the magnetic compass used in steering the craft. Just as in ocean navigation, it has become necessary in aerial navigation, though not yet to the same degree of refinement as in ocean work, to determine the effects on the compass of the magnetic materials used in the construction and in the equipment of the aircraft. The airship compass must, accordingly, be compensated, and allowance for any outstanding errors must be made in steering a course with it.

Besides the so-called "magnetic-deviation errors" of the compass, arising from the magnetic materials in the vicinity of the compass, there are other errors which make themselves seriously felt, only, however, while the aeroplane is turning. The latter are called "dynamic-deviation errors"; their magnitude depends upon the tilt of the aeroplane, the magnetic dip, and the heading of course of the airship.

While the dynamic deviations may be large during turns of the aeroplane, yet they disappear, practically, when straight flight is resumed. Accordingly, there is doubt as to the desirability of adopting movable compensating devices such as suggested by Starling, which, while effective during aeroplane turns, might introduce magnetic deviations of a more permanent character during the more usual straight flights. If such devices are used they will require careful control.

In connection with the use of the compass in aerial navigation, an interesting scientific question comes up as to the change of the Earth's magnetic field, or of the magnetic elements with altitude above the surface. Magnetic experiments of this nature were made in balloons by Gay Lussac and Biot in 1804, which were repeated, with more success, a half century later by Glaisher. The available observations to date do not possess, however, the requisite refinement, and it is hoped that some day a non-magnetic airship and the necessary instrumental appliances will be available for conducting a magnetic survey of the aerial regions in the same manner as that employed in the ocean-magnetic survey of the non-magnetic ship, the *Carnegie.*

Experiments concerning "magnet-photography." L. A. Bauer and W. F. G. Swann. Physical Rev., ser. 2, vol. 9, 563–564, June 1917. (Abstract of paper presented at the joint meeting of the American Physical Society and the American Association for the Advancement of Science, New York, December 26, 1916.)

In the *Scientific American* for November 4, 1916, are recorded a number of experiments by F. F. Mace, on the influence of a magnetic field in stimulating photographic action of a set of miscellaneous articles. In Mace's experiments, both electromagnets and permanent magnets were used. The photographic plate was placed, film side up, on the top of the magnet, and the articles were placed on the film. The whole was covered with a bell-jar, which was bound around with black cloth and evacuated. After allowing the apparatus to stand in a light-tight room for lengths of time which varied in different experiments, impressions of the articles were obtained.

In the present paper is described a repetition of Mace's experiments with an electro-magnet, the plate used being a Seeds No. 30. The articles used were: a disk of hard rubber, a disk of white pine, a lead ring, a hexagonal iron nut, an iron key, a copper washer, a piece of amber, and a lead disk. The bell-jar was exhausted with a Gaede box-pump for about half an hour, and then sealed off. After an exposure of 13 days, distinct impressions of the articles were obtained. The metallic articles and the hard rubber showed up lighter and the other articles darker than the ground. The grain of the wood was distinctly visible, but it is well known that wood will produce an action of this kind on a photographic plate, independently of the action of a magnetic field, the effect being primarily due to the resin in the wood. The appearance presented by the images of the metals was such as would be produced if they had acted as shields to a general radiation or other source of influence extending over the plate as a whole, and the main interest of the experiment here cited lay in the fact that the general darkening of the ground of the plate appeared to be much greater than was the case in the absence of the magnetic field, as subsequent experiments showed. (For continuation of experiments, see page 273.)

Preliminary ocean values of the annual changes of the magnetic elements as determined from the *Galilee* and *Carnegie* results, 1905–1917. L. A. Bauer, W. J. Peters, J. P. Ault, and C. C. Ennis.

The frequent intersections of the *Carnegie's* tracks, November 1916 to March 1917 (San Francisco to Buenos Aires), with the previous ones of the *Galilee* and the *Carnegie*, gave opportunity for amplifying tables 97 and 98, published on page 433 of Volume III (Researches of the Department of Terrestrial Magnestism). The same methods were used as described on pages 431 and 432 of that volume. For the sake of completeness table 96 is also given here as table 3, though no new values were added. As will be seen from tables 3, 4, and 5, the preliminary values of the annual changes are of the same general order of magnitude as disclosed by observations on land. The discussion of the values is deferred until additional data have been obtained.

TABLE 3.—*Average annual changes for the Indian Ocean.*[1]

Lat.	Long. east of Gr.	Approx. dates showing time-intervals.	Average annual change. D.	Average annual change. I.	Average annual change. H.	No. of values used to obtain annual change. D.	No. of values used to obtain annual change. I. and H.	Least No. in any group D.	Least No. in any group I. and H.
°	°		′	′					
37.5 S	25.9	1902.4–1911.4	11 E	....	...	10 and 5	......	5	..
25.3 S	60.6	1903.4–1911.6	5 W	....	...	4 6	......	4	..
35.3 S	74.8	1903.3–1911.4	13 W	....	...	7 12	......	7	..
36.0 S	95.4	1911.9–1916.1	17 W	2 S	−7	5 11	5 and 7	[2]5	[2]5

[1]The first three entries of the table are derived from the intersections of the tracks of the *Carnegie* in 1911 with those of the *Gauss* (the vessel of the German Antarctic Expedition, 1902 and 1903); see Terr. Mag., v. 16, p. 136, 1911.
[2]Two groups only.

TABLE 4.—*Average annual changes for the Atlantic Ocean.*

Lat.	Long. east of Gr.	Approx. dates showing time-intervals.	Average annual change. D.	Average annual change. I.	Average annual change. H.	No. of values used to obtain annual change. D.	No. of values used to obtain annual change. I. and H.	Least No. in any group. D.	Least No. in any group. I. and H.
°	°		′	′					
50.4 N	331.3	1909.8–1914.5	4 E	1 S	0	3 and 3	4 and 5	[2]3	2
49.5 N	352.7	1909.8–1913.7	7 E	....	...	5 8	......	[1]3	..
48.4 N	343.0	1909.8–1913.7	8 E	3 S	+5	7 7	4 5	2	2
48.3 N	311.2	1909.8–1914.7	4 E	4 S	+4	7 9	3 6	2	1
46.2 N	346.5	1909.8–1913.7	.....	6 S	+3	....	7 9	..	2
42.8 N	299.7	1909.7–1914.8	5 W	....	...	5 9	......	1	..
42.7 N	343.9	1909.9–1913.7	4 E	6 S	+5	7 8	4 5	2	2
42.4 N	297.2	1909.7–1914.8	.....	1 N	−4	....	4 6	..	2
39.0 N	291.1	1909.7–1915.2	[3]3 W	....	...	34	......	[3]34	..
38.1 N	342.8	1909.9–1913.8	6 E	3 S	+1	6 7	4 4	2	2
21.1 N	325.2	1909.9–1913.6	7 W	10 S	0	10 9	7 4	4	2
54.4 S	295.8	1913.1–1917.1	4 W	4 N	−5	18	12	18	12

[1]Three groups only. [2]Two groups only.
[3]One adjustment of 34 results; probable error ±1′.5.

The annual changes for the declination (*D*) and inclination (*I*) are invariably referred to the north-seeking end of the magnetic needle. Thus 6′ W means that the north-seeking end of the compass moved to the west at the annual average rate of 6′ during the period shown in the third column of the tables; 1′ N means that the north-seeking end of the dip needle moved downwards at the average annual rate of 1′ during the period in the third column. The annual changes for the horizontal intensity (*H*) are given in units of the fourth decimal C. G. S.

TABLE 5.—*Average annual changes for the Pacific Ocean.*

Lat.	Long. east of Gr.	Approx. dates showing time-intervals.	Average annual change.			No. of values used to obtain annual change.			
			D.	*I.*	*H.*	*D.*	*I.* and *H.*	Least No. in any group.	
								D.	*I.* and *H.*
°	°		′	′					
46.0 N	159.2	1906.7–1916.6	.....	1 N	−2	....	6 and 7	..	2
45.9 N	162.8	1906.7–1916.6	6 W	....	...	7 and 13	......	1	..
45.4 N	164.1	1906.7–1915.6	6 W	1 S	−2	3 8	6 8	1	2
42.8 N	221.6	1906.8–1916.7	2 E	0	−2	2 10	4 7	[1]2	2
42.0 N	190.4	1907.0–1915.5	4 W	5 S	0	7 9	4 6	3	2
41.2 N	222.3	1907.6–1916.7	2 E	1 S	+1	6 10	6 7	3	2
39.2 N	231.6	1906.8–1916.7	4 E	0	−2	3 7	3 5	1	1
36.7 N	150.5	1906.7–1916.6	.....	2 N	−3	....	4 3	..	[2]3
30.3 N	144.1	1906.6–1916.6	3 W	0	−1	8 8	5 4	3	2
27.2 N	199.3	1905.9–1915.5	2 E	....	...	8 7	......	[2]7	..
26.4 N	131.0	1907.4–1912.3	0	2 S	+2	6 5	5 8	2	2
19.5 N	218.2	1906.2–1915.4	4 E	1 N	−2	7 12	7 6	3	3
17.6 N	144.3	1906.6–1916.6	.....	1 S	−1	....	3 4	..	1
16.5 N	243.9	1908.3–1916.9	.....	1 N	−5	....	4 6	..	2
15.3 N	174.6	1907.8–1912.3	5 W	2 N	0	5 6	4 4	2	2
15.3 N	174.6	1912.3–1916.5	3 W	1 S	−7	6 11	4 5	2	2
14.5 N	236.5	1907.5–1915.4	.....	6 N	−1	....	5 7	..	2
13.4 N	239.9	1907.8–1915.4	2 E	....	...	8 7	......	[2]7	..
11.9 N	244.8	1908.3–1915.3	.....	4 N	−2	....	4 4	..	2
7.6 N	164.1	1906.5–1915.7	1 W	7 S	−2	6 12	5 5	3	2
6.0 N	234.0	1907.0–1912.6	6 E	5 N	−2	6 16	6 15	2	2
3.0 N	246.4	1908.3–1916.9	5 E	4 N	−2	4 12	6 6	2	3
2.0 N	161.4	1907.2–1915.7	3 W	5 S	−3	5 14	6 8	2	3
1.8 N	244.8	1912.6–1916.9	3 E	....	...	6 12	......	6	..
1.4 N	244.1	1912.6–1916.9	.....	4 N	−9	....	6 6	..	3
0.4 N	246.6	1908.3–1912.6	4 E	4 N	+4	3 5	4 4	[2]3	[2]4
1.5 S	178.6	1906.4–1912.4	2 W	6 S	+1	6 8	6 8	3	3
5.3 S	176.5	1907.2–1912.4	1 W	2 S	−3	4 10	5 7	1	2
11.8 S	216.3	1907.1–1912.7	7 E	0	−3	6 10	6 6	2	2
14.6 S	246.0	1912.6–1917.0	0	....	...	13 12	......	5	..
15.2 S	246.0	1912.6–1917.0	.....	3 N	−7	....	13	..	[1]3
26.5 S	268.5	1908.1–1913.0	0	4 N	−4	7 8	6 6	3	3
28.5 S	223.1	1912.6–1917.0	3 E	....	...	20	......	20	..
29.4 S	242.1	1912.6–1917.0	5 E	2 N	0	33	17	33	17
30.1 S	222.7	1912.6–1917.0	.....	8 N	−4	....	12	..	12
31.0 S	187.8	1912.5–1916.4	4 E	1 S	−6	6 13	6 6	2	3
38.4 S	221.8	1912.8–1917.1	.....	1 N	−2	....	22	..	22
39.3 S	220.3	1908.1–1917.1	3 E	....	...	23	......	23	..
39.3 S	220.3	1912.8–1917.1	1 E	....	...	32	......	32	..

[1]Three groups only. [2]Two groups only.

Further experiments concerning "magnet-photography." L. A. Bauer and W. F. G. Swann. (Abstract of paper presented before the American Physical Society, New York, February 15, 1917.)

The paper describes a continuation of the work outlined in the abstract on page 270. A large number of experiments have been performed, and it is impracticable to give more than a general survey of the work. In all of the experiments in which articles were exposed to the influence of a magnetic field in the manner already described, a subsidiary plate was set up with a similar set of articles, but beyond the influence of the magnetic field. In the earlier experiments, this subsidiary plate was placed in an ordinary plate-box at atmospheric pressure, the box being bound around with dark cloth; but in the later experiments it was placed in the same vacuum as the main plate, and shielded from the magnet by an iron disk. All experiments except the first two or three performed were carried out in total darkness, the photographic red light only being turned on after the articles had been mounted under the bell-jar, and the latter had been bound around with black cloth.

In order to test whether the effects observed could be attributed to radioactive material, two experiments were set up with permanent magnets, but in the case of one of them the bell-jar was washed out with a weak solution of uranium nitrate and allowed to dry. After an exposure of 21 days, the articles showed up equally strongly on both plates.

A plate was exposed for 6 days over an electromagnet, the articles being pieces of wood, iron, copper, amber, and cork; also, in addition, a piece of wood resting on a piece of lead which was in contact with the plate, and a piece of lead resting on a piece of wood which was in contact with the plate. Both pieces of wood in contact with the plate showed up dark on a lighter ground, the grain of the wood being very clear, and the cork showed up slightly darker than the ground. The metals in contact with the plate all came out lighter than the ground. In the case of the subsidiary plate which was set up at atmospheric pressure, only the amber showed up, and this appeared dark on a light ground.

Several experiments made with the articles slightly separated from the plate showed that their influence fell off rapidly within a distance of 1 or 2 mm.

The *effect of resin* in acting upon a photographic plate, especially when the resin has been previously stimulated by light, is well known, and at once suggests the assumption that the resin wood, cork, etc., produce a radiation of some kind, or a gaseous emanation, the latter being produced either directly or as a result of the radiation, and that this gas diffuses over the body of the plate and darkens it. In this case the metal articles would simply act as shields to the plate. Experiments made with stimulated resin and metallic articles showed that distinct impressions of the articles could really be produced in this way without a magnetic field or a vacuum. At atmospheric pressure the darkening of the plate falls off rapidly with the distance from the resin, but on evacuating the space around the resin the "range" of the action is increased and the impressions are much more uniform.

A large number of experiments were made with stimulated resin, and it appeared that the action was propagated roughly in a linear manner for a distance of as much as a centimeter or more, and after traversing this distance was still capable of passing through aluminum leaf.

The apparent action of the magnetic field in the experiment with wood and metal articles suggests that a similar action should be produced in the case of the resin. If the action of the resin is ultimately attributable to the ejection of charged particles, the possibility of producing deviation by a magnetic

field at once suggests itself. No marked influence of this kind was, however, found in the case of the pure resin.

One of the most remarkable features of the photographic action produced in the case of wood and metal articles is that it is approximately uniform over the plate, although the magnetic field varies both in magnitude and direction. If the action of the magnetic field were one of controlling the direction of propagation of a radiation or gaseous effusion emitted by the substances, one would expect it to vary over the surface of the plate. The absence of such variation practically limits the nature of the effect to one in which there is direct or indirect stimulation of the activity of emission or production of active gas, diffusion being subsequently relied upon for the uniform distribution of the effect over the plate.

The *effect of very slight temperature changes* in modifying the action of metallic articles upon a photographic plate is well known, and one has to remember that an electromagnet becomes appreciably warmed during its excitation.

The presence of resinous articles does not seem wholly necessary for the production of the apparent magnetic effect. Thus, for example, a number of metal articles, namely, lead, iron, nickel, copper, and brass, were set up over an electromagnet in a vacuum for 14 days, and a similar group was set up in the same vacuum, but in a region shielded from the magnetic field. The first set produced strong impressions, light on a dark ground, while the second set produced no appreciable effect. The experiment was repeated with a permanent magnet and an exposure of 21 days, with similar but less pronounced results.

At the stage of the work recorded in the paper here abstracted, the preliminary conclusion was reached that while a magnetic field or vacuum was not essential to the production of effects of the kind recorded by Mace, the magnetic field appeared to have an effect in intensifying the action in certain cases. *The experiments are being continued with the object of ascertaining whether the primary agency producing the effect, in the case of the electromagnets, for example, is really the magnetic field itself or some other influence accompanying the production of the magnetic field.*

Preliminary summary showing results of direct comparisons of magnetic-observatory standards during 1915 to 1917 by the Department of Terrestrial Magnetism. J. A. Fleming.

Table 6 gives results of direct comparisons of magnetic-observatory standards obtained by observers of the Department of Terrestrial Magnetism since those summarized in Table A, page 278, Volume II, Researches of the Department of Terrestrial Magnetism. East declination and inclination of north end of needle below horizon are regarded as positive. The various footnotes will give the additional explanations required with regard to any particular standards, or as to recent changes in them. (See next page.)

The radium content of sea-salt specimens, collected on the fourth cruise of the *Carnegie*. C. W. Hewlett.

The method adopted for estimating the radium content is that suggested by J. Joly, and used by him for estimating the radium content of rocks. The sample to be tested is heated with fusion mixture in a nickel or platinum boat supported in a suitable tube surrounded by an electric furnace. The expelled gases, after passing through a tube of soda-lime, are collected in a rubber bag, from which they may be subsequently sucked into an ionization chamber, which has been previously exhausted by means of a pump. By

TABLE 6.—*Preliminary summary of results of direct comparisons of magnetic-observatory standards.*

Observatory.	Approximate.			Date.	I. M. S.[1]—Observatory.			Grade of value.			Observatory instruments.		C. I. W. instruments.	
	D	H	I		ΔD	$\frac{\Delta H}{H}$	ΔI	ΔD	$\frac{\Delta H}{H}$	ΔI	Magnetometer.	Inclinometer.	Magnetometer.	Inclinometer.
	°	*c.g.s.*	°		′		′							
Agincourt.....	− 6	.160	+75	[2]1915, Dec.....	....	....	−0.1	..	..	*a*	....	Toepfer EI. 89..	....	Schulze EI. 48.
Cheltenham...	− 6	.194	+71	1915, June.....	[3]−0.4	[4]−.00014	[5]+1.5	*a*	*a*	*b*	Wild 26.......	Wild EI. 26.....	26	EI. 26.
				1917, Jan......	....	....	[6]+0.8	..	..	*a*	Wild 26.......	Wild EI. 26.....	26	EI. 26.
Eskdalemuir...	−18	.167	+70	1915, Sep......	−0.8	−.00097	−0.1	*a*	*a*	*a*	Elliott 60......	Schulze EI. 103.	26	EI. 26.
Stonyhurst....	−17	.173	+69	1915, Sep......	0.0	+.00010	−1.4	*b*	*b*	*b*	Jones.........	DC. 159; 1, 2...	26	EI. 26.
Greenwich....	−15	.185	+67	1915, Aug., Oct.	−1.6	−.00058	−0.7	*b*	*a*	*a*	Declinometer and Gibson 3.	EI............	26	EI. 26.
Kew.........	−15	.184	+67	1915, Aug., Oct.	0.0	−.00047	−0.1	*a*	*a*	*a*	Jones[7].........	DC. 33; 1, 2[8]....	26	EI. 26.
Honolulu.....	+10	.290	+40	1915, May, June	0.0	[4]+.00009	−0.2	*a*	*a*	*a*	Cooke 36......	Schulze EI......	5 and 25	EI. 25.
Hongkong....	0	.372	+31	1915, Feb......	+0.4	+.00114	−1.8	*c*	*c*	*c*	Elliott 55......	DC. 71; 3, 4, 7, 8.	9	DC. 177; 1, 2, 5, 6.
Rio de Janeiro[9]	−10	.246	−15	1915, Mar.....	−1.0	([10])	−0.7	*b*	..	*c*	Cooke 25......	DC. 8075; 1, 2..	19	DC. 19; 1 and 2 of 21.
Pilar.........	+ 8	.255	−26	1917, Mar., Apr.	−0.7	+.00002	−0.1	*a*	*a*	*a*	Kew 175......	Toepfer EI. 3...	5 for D; 25 for H	EI. 25.
Samoa........	+10	.354	−30	1915, May.....	−3.6	+.00051	+1.4	*b*	*b*	*b*	Tesdorpf 2025..	Schulze EI. 2...	14	DC. 14; 1, 2, 5, 6.
Christchurch..	+17	.224	−68	[11]1915, Nov.....	+0.6	+.00091	+0.4	*a*	*a*	*a*	Cam. Sci. Inst. Co. 1.......	Toepfer EI. 109.	5 and 25	EI. 25.

[1]International Magnetic Standards as defined in Vol. II, Res. Dep. Terr. Mag., pp. 270–278.
[2]These comparisons were obtained at the Standardizing Magnetic Observatory of the Department of Terrestrial Magnetism, Washington, D. C.
[3]Referred to new mark and azimuth adopted by the Observatory.
[4]Referred to the new Coast and Geodetic Survey standard adopted from 1913 and equivalent to the standard previously used decreased by $0.0010H$.
[5]There was a change with regard to the Cheltenham earth-inductor between 1910 and 1913; see Res. Dep. Terr. Mag., Vol. II, p. 226, and footnote 4 of this table.
[6]Wild earth-inductor 26 was overhauled and somewhat modified after the comparisons of June 1915, so that the axis of rotation could be precisely oriented in the magnetic meridional plane for each observation.
[7]The Jones magnetometer was overhauled during 1914, but Dr. Chree states that careful examinations of both declination and horizontal-intensity base-values before and after overhauling led to the conclusion that no appreciable change had been made for resulting values of declination and intensity.
[8]Dr. Chree states that the dip circle and needles are the same as used in previous comparisons, but notes that the average difference on modern Dover dip-circles has been a trifle less since he succeeded Mr. Baker, who retired at the end of September 1912, as principal dip-observer.
[9]New magnetic observatory located at Vassouras, 77 km. northwest of Rio de Janeiro.
[10]Final intensity values for the Observatory are not yet available.
[11]Comparisons were also obtained in December 1915 and in April 1916, but the Observatory data required for the compilations are not yet available.

the aid of a suitably arranged series of taps, air from the atmosphere may be admitted so as to wash out completely the residual gases from the furnace and into the ionization chamber. Owing to the evolution of chlorine, it was found necessary to allow the gases to pass into a flask loosely packed with silver shavings before they passed into the ionization chamber. The wall of the ionization chamber was supplied with a potential of 100 volts, and its central rod was connected to the fiber of a unifilar electroscope.

The specimens of salt having been dried out, they were sealed in thin-walled glass tubes, provided with narrow openings which could be closed with a little molten wax. After remaining sealed for an appropriate time, a tube was introduced into the furnace and a determination was carried out. The wax melted and released the gaseous contents before the pressure had risen sufficiently high to burst the tube, and the glass tube itself became subsequently dissolved in the process of heating the fusion mixture. The apparatus could be subsequently standardized by fusing a known amount of analyzed carnotite with fusion mixture.

The samples of salt examined were those collected by the *Carnegie* on her fourth cruise in the Pacific and Sub-Antarctic Oceans. The radium content was found to be negligibly small compared with the values found by J. Joly and others for salt collected near land. It is to be noted, however, that the present samples are from ocean areas far removed from land. Former observers, including Joly, have concluded that the radium-content diminishes with increase of distance from land, so that the *Carnegie's* results are in harmony with this conclusion.

The report on the above investigation appeared in the December 1917 issue of *Terrestrial Magnetism.*

On the origin of the Earth's electric charge. W. F. G. Swann. [Abstract] Jour. Wash. Acad. Sci., vol. 7, No. 9, 270–271 (May 4, 1917), Washington. Physical Rev. ser. 2, vol. 9, No. 6, 555–557 (June 1917), Lancaster, Pa. (Papers presented before the American Physical Society, New York, February 15, 1917, and the Philosophical Society of Washington, March 17, 1917.)

Measurements of the variation of the penetrating radiation, with altitude, point to the upper atmosphere as the origin of a part of this radiation. The whole of the penetrating radiation is probably of the γ-ray type, but the part which reaches the Earth's surface from the outer atmosphere is naturally the most penetrating part. Indeed, it is so penetrating that it passes through a thickness of air which would be equivalent, in absorptive action, to a column of mercury 76 cm. high, if absorption coefficients were simply proportional to density and were independent of material. The γ-ray radiation from the outer layers of the atmosphere is consequently very "hard," and, in accordance with the known results of laboratory experiments, we must conclude that the negative corpuscles which it emits from the air molecules are emitted almost entirely in the direction of the radiation, and further, that they can have a range in air at least equal to that of the swiftest β-rays from radium products. The emission of corpuscles by these γ-rays will consequently result, at each point of the atmosphere, in a downward corpuscular current of negative electricity. This corpuscular current will charge the Earth until the return conduction current balances the corpuscular current at each point of the atmosphere.

Taking, for the purposes of this abstract, a simplified case where the penetrating radiation considered is all directed vertically downwards, if q is the number of corpuscles liberated per cubic centimeter per second by the pene-

trating radiation, and h the average distance which a corpuscle travels from its point of origin, the corpuscular current density will be

$$i = \frac{qeh}{2}$$

The average value of the air-earth current-density as obtained from several stations is 6.7×10^{-7} E. S. U. per square centimeter, so that if q be taken as 3, which is about equal to the number of pairs of ions produced per cubic centimeter per second in a closed vessel as a result of the part of the penetrating radiation in question, the value of h necessary to account for the above mean current-density is 9 meters. This value is quite within the range of possibility, since Eve has observed β-rays, from radioactive substances, with a range of 7 meters.

The corpuscular current-density, and consequently the conduction current-density, will not necessarily be independent of the altitude, for the factors upon which i depends, viz, the intensity and quality of the penetrating radiation, the number of molecules per cubic centimeter available for possible ionization by the radiation and the range of the corpuscles set free all change with the altitude.

Perhaps the principal difficulty confronting the above is the following: It may be argued that, while there is no primary objection to assuming that corpuscles may be ejected from the molecules of air with a speed sufficient to give them a range of 9 meters, nevertheless, if we do assume this, are we not forced to expect that, during the process of their absorption by the atmosphere, these corpuscles will produce many more ions? In this case, the 3 ions produced per cubic centimeter per second as an apparent result of the penetrating radiation are really to be considered as the net outcome of a very much smaller number of corpuscles originally set free by the penetrating radiation directly. Quite apart from the matter of the Earth's electric charge, if we do assume that each of the corpuscles originally emitted by the penetrating radiation is capable of producing a large number of ions, the meaning to be attached to the ionization as measured in a closed vessel assumes a very indefinite form, as a little consideration will show. Yet, theory practically forces us to the conclusion that corpuscles emitted by a radiation as penetrating as the penetrating radiation coming from above are emitted with speeds comparable with the swiftest β-rays of radioactive substances.

Experiment shows that the number of ions produced per centimeter of path diminishes with increase of velocity of the corpuscle, and attains a value of about 40 ions per centimeter for velocities comparable with that of light. A vital feature of this diminution of ionization is the fact that as the velocity of the corpuscle increases, the time during which it is in a position to act effectively for ionization, during its passage by a molecule, gets shorter. Now when velocities *very* near to that of light are attained, the concentration of the corpuscles' tubes of force in the equatorial plane perpendicular to its motion becomes increasingly important, although this phenomenon is of negligible account for such velocities as have figured in the measurements on ionization. A corpuscle moving with a velocity actually equal to that of light would exert no electric force except in its equatorial plane, and there the force would be infinite. Its mode of ionizing during its passage by a molecule would thus be one of applying an infinitely large force for an infinitesimal time. The electron to be ejected from the atom would have to suffer an enormous acceleration in order to take advantage of the momentum offered to it, and a very great amount of energy would be wasted in the acquisition of the momentum. In other words, a very much larger amount of energy would have to leave the

corpuscle during the ejection of the electron than would be the case in ionization by a slowly moving corpuscle. It is not possible, in this abstract, to cover many difficulties which may suggest themselves, but the arguments cited serve to show that, in so far as we have at present knowledge of the laws of ionization by very swiftly moving corpuscles, there is theoretical support for the view that as the corpuscular velocity approaches that of light, the efficiency of ionization falls off with great rapidity in the vicinity of that velocity. It may in fact be that for these corpuscles absorption takes place by the complete transfer of the energy of the corpuscle into the γ-ray type during absorption by an atom, in the manner outlined by Bragg, the γ-ray produced being of a quality such as to be capable of subsequently ejecting another corpuscle with a speed equal to that of the corpuscle which produced it.

Note concerning the measurement of ionic density on the top of a tower. W. F. G. Swann. Terr. Mag., vol. 22, 125–127 (Sept. 1917). Washington.

P. L. Mercanton has recently published results of measurements of the atmospheric ionization made by him on a parapet near the top of a tower and in the interior of the tower at its base.[1] He finds that if n_+ and n_- refer respectively to the positive and negative ionic densities, n_+/n_- is much larger for the measurement made in the strong electric field near the top of the tower than in the zero electric field in the interior of its base. Thus, for n_+/n_- as measured at the top of the tower, values 4.33, 2.16, 4.46, and 1.70 were obtained on four different occasions, while the corresponding values for the foot of the tower were respectively 1.31, 1.09, 1.24, and 1.19.

Attention is called to the confirmation afforded by these observations of the view put forward by the author, in a former communication,[2] as to the effect of the charge induced on the Ebert ion-counter, by the potential gradient, in modifying the values obtained in ionic-density measurements. The theory of the phenomenon shows that, for a potential gradient of the normal sign, measurements of n_+ should be unaffected by the induced charge, while those of n_- should be too small. The effect of the negative induced charge on the instrument is to retard the velocity of the approaching negative ions, so that they move slower than the incoming stream of air, with a result that fewer ions enter the instrument per second than would enter if there were no induced charge. The positive ions are accelerated by the induced charge, but theory shows that the *excess* number of ions entering the instrument is just equal to the number which are captured by the outer cylinder of the apparatus, so that the measurements of n_+ are unaffected by the induced charge. These conclusions are consequently in complete harmony with P. L. Mercanton's results, since they predict small values of n_- and consequently large values of n_+/n_- for places where the potential gradient is high, as, for example, on the top of a tower.

Reference is further made to some data recently published by A. Gockel concerning the effect of a tower on the ionic density in its vicinity.[3] In the paper already cited,[4] the problem of the tower is considered, and it appears that, as regards the *true negative ionic-density* (n_-), the space around the tower may be divided into two regions—a region in which there are no negative ions and a region external to this, in which the ionic-density is normal. For low potential

[1]Terr. Mag., vol. 22, pp. 35,–37, 1917. [2]Terr. Mag., vol. 19, pp. 205–218, 1914.

[3]Luftelectrische Beobachtungen im schweizerischen Mittelland, im Jura und in den Alpen. Neue Denkschriften der schweizerischen Naturforschenden Gesellschaft, vol. 54, No. 1, pp. 34–35, 1917.

[4]Terr. Mag., vol. 19, pp. 205–218, 1914.

gradients or strong winds the former region would be evanescent, or practically so. In any case, however, for a region outside the latter region, n_- should be normal. Theory also shows that n_+ has its normal values at all points of the space around the tower.

A. Gockel has made two sets of measurements, one on the top of a tower 13 meters high, and the other on a platform shielded from the potential gradient, and situated 2 meters below the top of the tower. For the measurements in the region exposed to the field he finds $n_+/n_- = 2.03$, while for the shielded region $n_+/n_- = 0.92$. He considers these measurements inconsistent with the above-cited views as to the action of the tower. It must be remarked, however, that we must here carefully distinguish between two distinct phenomena. As already stated, theory shows that n_+ and n_- have their proper values in the space around the tower for points outside the critical region; but when we introduce an *instrument* to measure the ionic densities, the error caused by the induced charge on the instrument produces its effect just as it does when measurements are made over the surface of the ground. It would thus appear that the difference between the values of n_+/n_- for the shielded and the unshielded positions is attributable to the induced charge on the instrument in the latter case, and there is no evidence to show that it is due to the tower directly. In order to reduce the instrumental error, it is necessary to shield the instrument with wire netting, as discussed on pages 210–212, and on page 215 of the paper already cited.[1]

An apparatus for automatically recording the electrical conductivity of air. W. F. G. Swann.

The apparatus is a modification of that of Gerdien, in which the conductivity is measured by passing the air through the space between two concentric cylinders, and noting the rate of fall of potential of the central member, which is initially charged to a potential of the order of magnitude of 100 volts.

In the present apparatus, the central cylinder is connected to one quadrant of a quadrant electrometer, the other quadrant being connected to the case of the electrometer which is insulated and maintained at a constant potential of say 100 volts. The two quadrants are permanently connected through a high-resistance radioactive cell, of the type developed by S. J. Mauchly and the author (Terr. Mag., vol. 22, pp. 1–21, 1917). Under these conditions, when air is passing through the instrument, the electrometer experiences a steady deflection, determined by the conductivity, the potential applied to the electrometer, and the resistance of the radioactive cell. The deflections are photographically recorded upon a rotating drum.

The usual form of Gerdien apparatus is subject to error on account of the collection of radioactive material from the atmosphere by the two concentric cylinders. In the present apparatus this error is avoided in the following manner: Before passing between the above two concentric cylinders, the air is caused to pass through the space between a set of concentric cylinders, which are divided up and connected into two groups in such a way as to cause the complete set to form one cylindrical condenser of capacity much greater than that of the two principal concentric cylinders. Once every hour a potential difference of 250 volts is applied for 3 minutes between the two units of this subsidiary set of cylinders, and thus, during these intervals, the ordinary small ions, which are usually the main agents in producing conductivity, are cleared out of the air before it passes through the main pair of concentric cylinders. On the other hand, the ions generated between the main cylinders

[1] Terr. Mag., vol. 19, pp. 205–218, 1914.

by the radioactive material previously collected still contribute their effect, so that the electrometer deflection falls, not to its true zero, but to a value determined by the radioactive effect; and the difference between this "apparent zero" and the deflection previously shown by the electrometer is the proper quantity from which to calculate the true conductivity of the air. It will, of course, be observed that any other variations of zero of the instrument become automatically eliminated by the above procedure.

In order to hasten the attainment of the appropriate zero-reading when the potential of 250 volts is applied, an automatic arrangement is included by which the two quadrants are first connected together for an instant through a potential difference just sufficient to cause the spot to settle down near the apparent zero-reading. The necessary potential-difference is obtained by utilizing a sort of potentiometer constructed from a graphite line drawn upon a sheet of ground glass, the ends of the graphite line being connected to the poles of a single cell, and contact being made to any desired point by another graphite line drawn to that point. The proportion of the E. M. F. of the cell tapped off by this potentiometer can readily be adjusted by rubbing out or thickening the graphite line on one side of the mid-contact point. The potentiometer system would be unnecessary were it not that, even when the electrometer is disconnected from the central cylinder, the reading obtained on joining the quadrants by a wire is appreciably different from that obtained when they are disconnected except through the radioactive cell.

The main central cylinder is insulated in an amber plug protected by a guard-ring which is kept at the potential to which the electrometer is raised.

If C is the capacity of the portion of the main concentric-cylinder system which is exposed to the air-current, V the potential to which the central cylinder is raised, λ the appropriate unipolar conductivity, and dQ/dt the rate of passage of electricity through the radioactive resistance, we have,

$$4\pi CV\lambda = \frac{dQ}{dt}$$

Arrangements are made by which the apparatus may be calibrated at any time and the quantity dQ/dt rapidly obtained in terms of the electrometer deflection. The scheme is such that the calibration data are printed directly upon the same trace as the conductivity record. The general method is as follows: To the part of the apparatus in permanent conducting communication with the main central cylinder is fastened a small brass cylinder which forms the inner member of a small cylindrical condenser. The outer member is connected to a sliding contact which moves on a long wire spiral wound on a drum, one end of the wire being connected to the earthed case surrounding the whole apparatus. Suppose now that ions are prevented from entering the apparatus by means of the attachment already described. If a potential difference is maintained between the ends of the spiral, and the latter is rotated so that the contact slides along it, the electrometer will deflect, and, eventually, a steady reading will be obtained which is determined entirely by the resistance of the radioactive cell, the rate of alteration of potential of the sliding contact, and a quantity k, representing the mutual capacity of the small cylinder connected to the sliding contact and the cylinder which surrounds it. If dV/dt is the rate of alteration of potential of the sliding contact, we have, for this case,

$$k\frac{dV}{dt} = \frac{dQ}{dt}$$

By altering the potential difference between the ends of the wire spiral, dQ/dt may be obtained for any value of the steady deflection, without varying the speed of rotation.

With the apparatus described, observations have been made for some months, and perhaps the most interesting feature of these observations is the importance which they assign to the ions of mobility smaller than those which are ordinarily supposed to figure in measurements of the conductivity. With the potential of 250 volts applied to the subsidiary attachment, ions of mobility greater than about 0.1 cm. per second per volt per centimeter should be cut out during the intervals of application of the potential. It frequently results that at night, and during periods of rain, the conductivity mounts to an abnormally high value, and that the ions mainly responsible for this phenomenon have a mobility at least as small as about 0.1 cm. per second per volt per centimeter is borne out by the fact that the apparent conductivity is not greatly reduced during the periods of application of the potential of 250 volts. The existence of a very high conductivity as a result of ions of very small mobility necessitates, of course, the presence of a very large number of these ions. It is not improbable that the very high ionic densities found on the occasions referred to are associated with a reduction of the rate of recombination of the ions as a result of their combination with nuclei. This would result in an increase in the number of ions present in the steady state. It is of interest to notice that the new steady state would take some considerable time to be set up. For, suppose the unipolar conductivity were of the order of 10^{-3} E. S. U., as is sometimes the case. If the mobility of the ions responsible for this conductivity were less than 0.1, there would be at least 60,000 ions per cubic centimeter. If the rate of formation of ions were as great as 10 per cubic centimeter per second, nearly 2 hours would be necessary for the production of these ions, even if there were no recombination.

Supplementary report on atmospheric-electric observations made aboard the *Carnegie* from May 17, 1916, to March 2, 1917. W. F. G. Swann.

The general scheme of the observations is similar to that described in Volume III, of Researches of the Department of Terrestrial Magnetism, but it was possible to secure a greater number of observations on the diurnal variation than heretofore.

Table 7 (p. 282) gives the dates of arrival at and departure from various ports, and the observations are grouped according to the parts of the cruise specified by these ports. The figures in parentheses give the numbers of days upon which observations were made, and the definition of the quantities in the table is as follows:

n_+ and n_-, the numbers of positive and negative ions per cubic centimeter.
λ_+ and λ_-, the conductivities for positive and negative ions.
v_+ and v_-, the specific velocities of the positive and negative ions.
X, the potential gradient.
i, the air-earth conduction current density.
R, the number of pairs of ions produced per cubic centimeter per second in a closed copper vessel of 27 liters capacity.
Ra. Em., the radium-emanation content of the air.

The means for all the observations are given in the line next to the last, and in the last line are given the means for all the observations already published for Cruise IV of the *Carnegie* through March 1917. The numbers in both cases are uncorrected for diurnal variation, and correspond to a mean time of about 9^h5.

In obtaining the mean value of the radium-emanation content from Easter Island to Buenos Aires, a few exceptionally large observations taken near the coast on approaching Buenos Aires, and obviously influenced by the proximity of land, have been omitted.

TABLE 7.—*Mean values of atmospheric-electric elements obtained on the fourth cruise of the Carnegie.*

Portion of cruise.	n_+	n_-	$\frac{n_+}{n_-}$	λ_+	λ_-	v_+	v_-	X volt/m	i E.S.U. $\times 10^{-7}$	R	*Ra. Em.* curies $\times 10^{-12}$/m^3
				E. S. U. $\times 10^{-4}$		cm./sec.	volt/cm.				
Lyttelton-Samoa (May 17 to June 7, 1916).	(9) 773	(8) 487	(8) 1.52	(12) 1.56	(11) 1.41	(7) 2.27	(7) 2.18	(17) 144	(11) 1.17	(15) 3.3	(6) 1.7
Samoa-Guam (June 19 to July 17, 1916).	(21) 772	(19) 631	(18) 1.32	(16) 1.46	(17) 1.32	(15) 1.38	(16) 1.59	(23) 137	(16) 1.29	(21) 3.2	(10) 0.4
Guam-San Francisco (Aug. 7 to Sept. 21, 1916).	(21) 870	(18) 614	(18) 1.39	(17) 1.04	(16) 0.82	(14) 0.83	(14) 0.85	(32) 140	(16) 1.14	(10) 3.1	(9) 12.1
San Francisco-Easter Isl. (Nov. 1 to Dec. 24, 1916).	(33) 739	(30) 538	(28) 1.47	(34) 1.27	(34) 0.99	(28) 1.26	(30) 1.38	(43) 130	(33) 0.99	(24) 3.2	(12) 7.3
Easter Isl.-Buenos Aires (Jan. 2 to Mar. 2, 1917).	(39) 849	(33) 624	(33) 1.36	(40) 1.28	(40) 1.01	(35) 1.12	(33) 1.19	(44) 126	(40) 0.94	(35) 3.7	(17) 2.0
Mean values.........	(123) 804	(108) 589	(105) 1.40	(119) 1.30	(118) 1.06	(99) 1.24	(100) 1.33	(159) 134	(116) 1.05	(105) 3.4	(54) 2.8
Mean values through March 1917.......	825	693	1.21	1.47	1.22	1.29	1.29	122	1.06	3.8	2.3

The new values are in very good general agreement with those for the period through March 1917, and, indeed, they suggest nothing to be added to or taken from the conclusions already published and based upon the former data.

In working up the diurnal-variation data, some of the material from the period up to March 1916, has been included, in order to obtain the mean diurnal-variation curve for a whole year. There is naturally some indefiniteness to the meaning to be attached to such a result on account of the great variation in latitude concerned. The diurnal variation has been investigated for the potential gradient, positive ionic content, and penetrating radiation. A Fourier analysis has been made for the first two, but for the purposes of abstract it is better to discuss the curves in general terms.

The diurnal variation of the potential gradient has been obtained from 20 sets of observations, ranging from February 25, 1916, to February 20, 1917. The curve shows its principal maximum about 9 a.m., in good agreement with the results through March 1916. A secondary maximum occurs about midnight, or a little earlier, but it is less pronounced than in the earlier observations, and this naturally results in the early-morning minimum being less pronounced than in the earlier observations. The afternoon minimum formerly found about 3 p. m. now appears somewhat later, about 6 p. m., and is less marked than before. In fact, speaking generally, the effect of the 12-hours Fourier wave is less important in the present curves than in those already published.

The diurnal variation of the ionic content has been obtained from 18 sets of observations ranging from February 25, 1916, to February 20, 1917. The curve shows a fairly regular variation with a maximum at midday and a minimum somewhat later than midnight, but which would have occurred almost exactly at midnight except for the interposition of a small secondary maximum about that hour, which interfered with the development of the principal minimum. In the observations already published there appeared a flat maximum, ranging from 6 a. m. to 2 p. m., and a minimum at midnight.

As before, the diurnal variation of the penetrating radiation appears too small to make its nature evident with certainty.

It is naturally not an easy matter to secure data on the annual variation in the case of ocean observations; nevertheless, in the various sections of the cruise, the *Carnegie* has covered the same range of latitude several times, and so it is possible to obtain some indication of the annual variation by meaning observations for a week or more taken at different times in the various latitudes. Thus, in the case of latitude 54° S., as a result of a four-point curve, the potential gradient was found to show a strong minimum in summer (January), and although the data for this latitude did not extend beyond March, the curve indicated an approximation to a maximum about April. The air-earth current-density showed a minimum in January and an indication of an approach to a maximum in the winter. The conductivity gave indications of a principal minimum in January, interrupted, however, by a weaker maximum about the same time. The negative ionic density was practically constant from December to March, but the positive ionic density showed a sharp change from a minimum in the middle of January to a maximum in the middle of February.

Conclusions with regard to the annual variation must necessarily be tentative at this stage, but it is hoped that they will become stronger and stronger as the data for their elucidation increases.

On the Detection of Single α Particles. W. F. G. Swann.

A method of detecting single α particles was first devised by Rutherford. In this method the α particle was caused to ionize air which was under such electric strain that it was just on the point of breaking down. The current passing between the electrodes during the passage of an α particle into this critical region was, under these conditions, very much greater than the saturation current which could be produced by the ionization of the α particle alone.

In the present work, the aim has been to increase the stability and sensitivity of the apparatus to such a degree that the saturation current due to the direct ionization produced by the α particle may be detected. If this can be accomplished readily and conveniently, a number of uses may be made of the method. Thus, for example, it becomes possible to form an estimate of the radium-emanation content of the atmosphere by counting the α particles emitted by the air in a closed vessel.

The general principle of the method is as follows: A vessel of about 30 liters capacity forms an ionization chamber in which the α particles produce their ionization. The central member of the ionization chamber is connected to the fiber of a unifilar electroscope. The wall of the chamber is supplied with a potential of about 500 volts, and the central member is protected from it by a guard-ring.

The system connected to the fiber is joined to the case of the electroscope through a resistance of the order of 1,011 ohms, constructed by depositing platinum upon a quartz fiber.

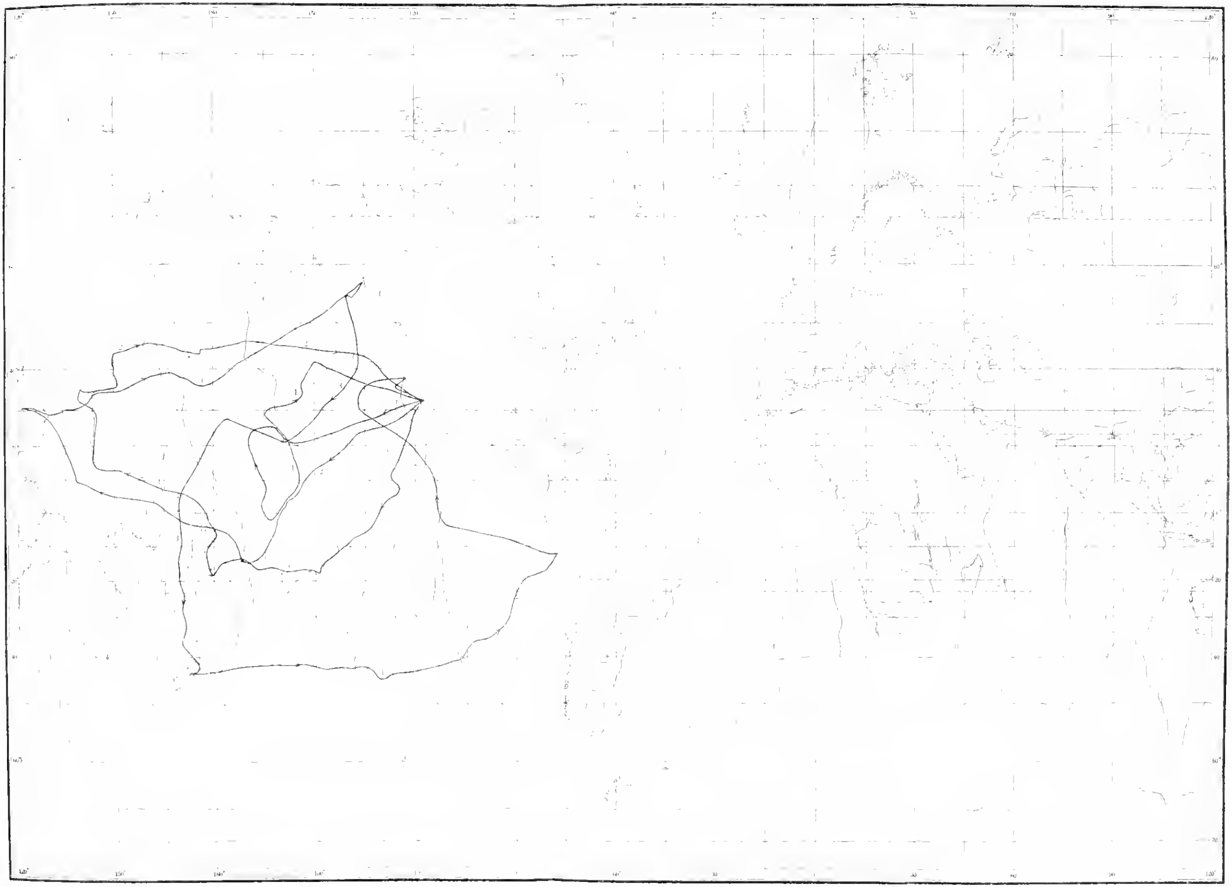
The plates of the unifilar electroscope, instead of being connected to the two ends of a battery whose mid-point is connected to the electroscope case, are connected to the two ends of a megohm. The megohm is connected across the battery and its mid-point is joined to the case of the electroscope. In this way it results that fluctuations in the E. M. F. of the battery affect both plates in equal and opposite directions, so that the electroscope is very much more stable than if the megohm were not employed. A sensitivity as high as 1,000

divisions per volt has been obtained by this method, and such a sensitivity is sufficient to result in an appreciable kick in the fiber each time an α particle is shot out in the ionization chamber.

A high potential is required on the wall of the ionization chamber, so that the ions may be brought to the central rod sufficiently rapidly to cause a sharp kick. This potential must be very constant, for if the electroscope is sensitive to 1,000 divisions per volt, it would respond to the extent of about 0.1 division if the battery on the ionization chamber fluctuated in potential by 10^{-4} volt. Hence, if the battery in question had an E. M. F. of 500 volts, it would have to be free from fluctuations to the extent of one part in 5,000,000. It would, in general, be impossible to obtain such a degree of constancy, but the equivalent of obtaining it has been secured as follows: To the system connected to the fiber is attached a brass cylinder, surrounded by another brass cylinder, which, however, does not touch it. Although the volume of the attachment is small, the capacity of the portion inclosed by the hollow cylinder is comparable with, and may be made nearly equal to, the capacity of the portion of the rod surrounded by the large vessel. The two ends of a megohm are connected respectively to the large vessel and to the outer cylinder of the attachment, the mid-point of the megohm being connected to the case of the electroscope. A battery of 1,000 volts is also connected to the two ends of the megohm. It will be obvious that, under these conditions, and when the capacities above referred to are adjusted to equality, fluctuations of the battery potential may take place without affecting the potential of the insulated system.

With the above apparatus it has been possible to detect and photographically record the ionization by a single α particle.

Experiments have also been made on a new form for plates of the unifilar electrometer, with a view to increasing still further the range and sensitivity of the instrument.



Map showing the Magnetic-Survey Work of the Department of Terrestrial Magnetism during the Period 1905-1917 (October).
(Black lines show the cruises of the *Galilee*, and red ones, those of the *Carnegie*. Red dots show the land stations.)

ARCHEOLOGY.

Morley, Sylvanus G., Santa Fe, New Mexico. *Associate in American Archeology.* (For previous reports see Year Books Nos. 13, 14, and 15.)

During the autumn, winter, and spring of 1916–17 work was continued on the inscriptions of Copan, Honduras, and was brought almost to a close. An examination of all the available texts was completed, and there remains only the preparation of a concluding chapter, appendices, index, and tables. This work was suspended in April, when the 1917 Central-American expedition took the field, sailing from New Orleans for Puerto Barrios, Guatemala, on April 26, under instructions to make an archeological reconnaissance of Central America, so far as that might be practicable. Mr. Morley was accompanied by Mr. John Held, jr., of New York, as artist, and the expedition will remain in the field indefinitely.

The first trip was an archeological reconnaissance of western Honduras, the itinerary of which is shown in figure 1, together with the locations of the new sites discovered. The expedition left Zacapa, Guatemala, on May 15, going first to the ruins of Copan, Honduras, where several days were spent in drawing and photographing the new texts, which had been discovered since the previous visit in March 1916. One of these, a fragmentary stela, to which the number 24 was

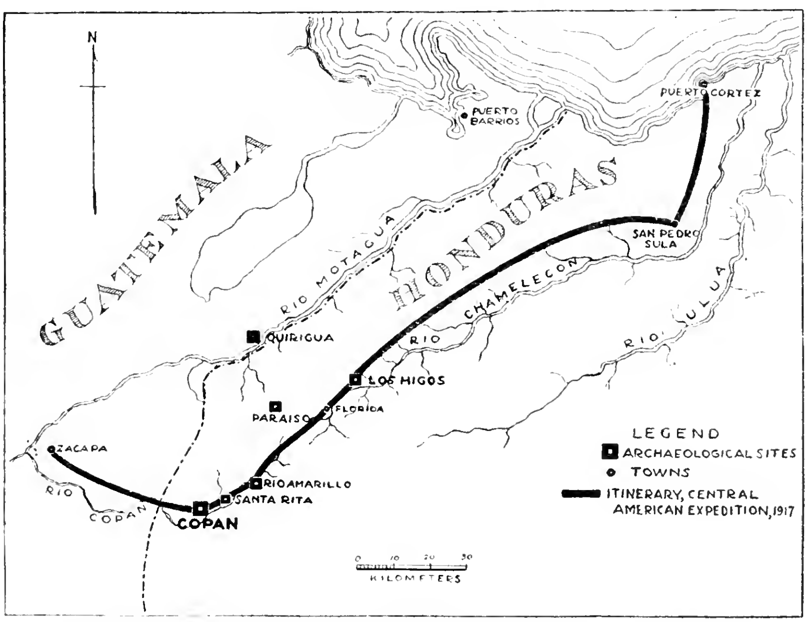


Fig. 1.—Map showing the itinerary of the 1917 Central American Expedition, and the cities of the eastern Maya frontier.

given, proved to be the earliest monument yet found at this site, recording the date 9.2.10.0.0 of the Maya Era, or approximately 210 A. D. (see fig. 2B).

The circumstances surrounding the discovery of this particular fragment are of special interest because of the light they shed upon a common Maya practice throughout the period of the Old Empire, namely, the re-use of earlier monuments in later constructions. This piece was found near the southwestern corner of the village plaza, 3 feet below the present level of the ground. It rested directly upon the foundation stone of Stela 7, in the support of which it seems to have been used. But the date of Stela 7 is 9.9.0.0.0 of the Maya Era, approximately 340 A. D.; in other words, Stela 24 was broken up and re-used in the foundations of this later monument 130 years after the date upon which it was originally erected (210 A. D.). This practice was known to have been common during the Middle and Great Periods of the Old Empire, but the present case is the first example of its occurrence as far back as the Early Period.[1]

The front and back of Stela 24 are inscribed with hieroglyphs, the sides being left plain, though dressed smooth. The single fragment was recovered from about 3 feet below the surface and presents the cycle, katun, tun, uinal, and day signs, all perfectly preserved and permitting the certain decipherment of the date as given above.

Another interesting point in connection with this monument is that it records a half katun ending (lahuntun), just like Stelæ 15 and 9, the next two earliest monuments at Copan; furthermore, each is 40 years apart from the next. Indeed, it is probable that the marking of the first and third quarters of the katuns (hotuns) did not commence until later, about the close of the Early Period.[2]

Stela 24, 9.2.10.0.0, approx. 210 A. D.
Stela 15, 9.4.10.0.0, approx. 250 A. D.
Stela 9, 9.6.10.0.0, approx. 290 A. D.

Stela 24 is 3 years earlier than the earliest date yet deciphered at Tikal and indicates that the antiquity of Copan, the southern Maya metropolis, may yet be found to exceed that of her great northern rival.[3]

A very fine altar of the Great Period, called W′ was discovered in a small plaza about a half mile east of the Main Group on the western bank of the river. The front was sculptured with a representation of the two-headed monster, and the back and sides with hieroglyphs. Many of the signs are the unusual full-figure variants, and the dedicatory date would appear to have been the hotun ending 9.17.5.0.0,

[1]To avoid confusion, the name of the earliest period of the Old Empire has been changed from Archaic to Early. It has appeared advisable to reserve the word Archaic for that truly archaic civilization, probably of Nahua origin, which overran the greater part of Mexico and Central America some time prior to the first period of Maya florescence.

[2]The earliest first or third quarter of a katun now known is that recorded on Stela 25 at Piedras Negras, namely, 9.8.15.0.0, approximately 335 A. D.

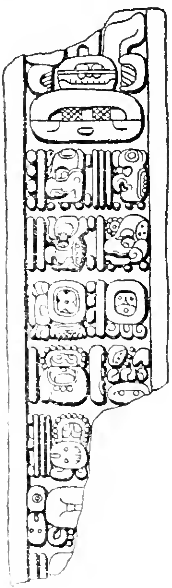
[3]For further data relating to this question, see Year Book No. 15, pp. 339–341.

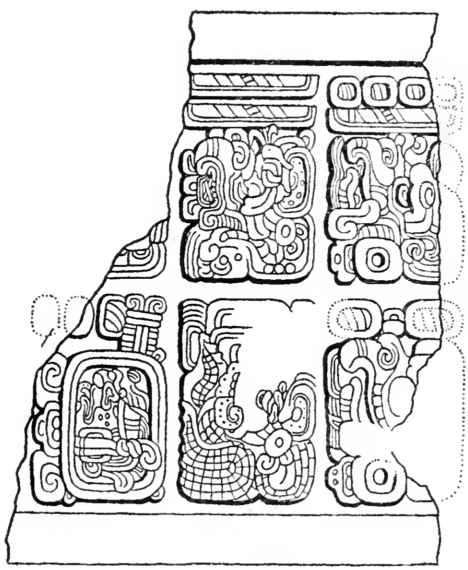
approximately 505 A. D. Photographs and drawings were made of all four faces.

Two of the three missing fragments of the East Altar of Stela 5 were also found during the past year in the bush just north of the stela. One of these presents Glyphs C, D, and E of the Supplementary Series. Photographs and drawings were made of the inscription.

The long-missing fragment of a Great Period Initial Series, photographed by Maudslay in the eighties, was located in the foundations of a house on the southern side of the village plaza and was removed to the cabildo for safe keeping. This piece is chiefly important as presenting the latest example of an Initial Series yet found at Copan. Several other fragments, probably referable to the Early Period, were found, and also removed to the cabildo.

A





B

FIG. 2.

A.—Stela 1. Los Higos, Honduras. This monument records the date 9.17.10.0.0 of the Maya Era, or approximately 510 A. D. It is in the best style of the Great Period of the Old Empire, which was the Golden Age of Maya Art.

B.—Stela 24. Copan, Honduras. This fragment of a monument presents the earliest date yet found at Copan, namely 9.2.10.0.0 of the Maya Era or approximately 210 A. D. One hundred and thirty years after its erection, it was broken up and used over again in the foundations of another monument.

The next site visited was Santa Rita, 7 miles up the valley from Copan, where Stela 23 was discovered last year.[1] A drawing of one of the sides omitted last year was made, which completes the record of this text.

The first of the two new sites discovered on this trip, Rio Amarillo, is on the bank of the Copan River, about 12 miles northeast of Santa

[1]See Year Book No. 15, p. 338.

Rita (see fig. 1). A number of mounds are built on the side of a hill, which has been artificially terraced, and at the eastern end, near the base, are two hieroglyphic altars. Unfortunately, although the inscriptions are perfectly legible, neither presents a date in the Long Count; and it is therefore impossible to assign either to its exact position in Maya chronology. From the style of carving, however, both are surely referable to the Great Period. It is to be regretted that not a single date can be deciphered here, although the approximate age of the site is doubtless determinable from the stylistic criteria. A map of the site, and drawings and photographs of both inscriptions, were made.

Leaving the Copan Valley and passing over the divide into the Chamelecon Valley, another new site was discovered at Los Higos, some 12 miles northeast of the village of La Florida (see fig. 1).[1] This site is on the west side of the Chamelecon River and an eighth of a mile back, at the base of the first foothills. It contains upwards of 30 mounds, including several fairly high pyramids and one very fine stela in the best style of the Great Period (see fig. 2A). The inscription is unusually well preserved and records the date 9.17.10.0.0 of the Maya Era, approximately 510 A. D. It is evident from this single piece of sculpture that the city derived its artistic inspiration from Copan; indeed, it was probably colonized from Copan during the Middle or Great Period. A map of the site was made, and the inscription was drawn and photographed.

One of the results of the past 4 years' work in this part of the Maya field has been the rather definite location of the eastern or southeastern Maya frontier.

During this period four new sites (Paraiso, Santa Rita, Rio Amarillo, and Los Higos) have been added to the two previously known (Copan and Quirigua) and the general historical development of the region has been worked out. A comparison of the earliest and latest dates at these six cities clearly establishes their relative ages.

Copan, 210–530 A. D.
Santa Rita, 380 A. D., only one date.
Quirigua, 475–540 A. D.
Rio Amarillo, 460–600 A. D., date based upon stylistic criteria.
Paraiso, 460–600 A. D., date based upon stylistic criteria.
Los Higos, 510 A. D., only one date.

Copan was the first settlement in this region, possibly being founded as early as the first century before Christ. Although Santa Rita had been founded as early as the beginning of the Middle Period, 380 A. D., it was not until the beginning of the Great Period, 100 years later, that the extensive colonization of the region really began. Quirigua was

[1]This site and monument were discovered through information furnished by Mr. Basil Booth, a mahogany contractor of Guatemala, and Mr. S. K. Lothrop, of the Peabody Museum of Harvard University.

founded in 475 A. D. or possibly 22 years earlier, and Los Higos was established shortly afterward, 510 A. D.

Although it has been impossible to date either Paraiso or Rio Amarillo exactly, both are certainly referable to the same general period on stylistic grounds, and we may accept the great extension of Maya dominion in the south as having taken place toward the close of the fifth century, beginning about 475 A. D.

The frontiers of Maya esthetic influence doubtless overlapped the frontiers of actual empire in most places. For example, the pottery of the Ulua Valley, which lies considerably east of this chain of cities, shows unmistakable Maya influence. Also, during the present field season a large collection of pottery from northwestern Salvador was found to contain many pieces almost exactly like those from the Copan tombs. Just as Rome influenced the life and art of the outer barbarians, so the Maya coerced the life and art of surrounding peoples of lower culture and imposed their esthetic standards and practices beyond the frontiers of their empire. The latter would appear to have been the chain of cities just described, whereas the former were strongly felt as far east as the Ulua Valley.

A second trip was made in Salvador and the central part of Honduras during July and August. Mr. Held made color drawings of the painted vases in the Justo Armas collection in San Salvador; and at Tegucigalpa he painted a magnificent specimen of Maya ceramic art from Copan. At San Pedro Sula a fine example of painted ware in the Waller collection from the Ulua Valley was also drawn in color. At Tegucigalpa occasion was taken to call upon His Excellency President Bertrand and Doctor Mariano Vasquez, the Minister of Foreign Relations, and to explain the work of the Carnegie Institution of Washington in Honduras, particularly at Copan. Friendly relations were established with these officials, and it is believed that the way was paved for more extensive work there in the future.

BIBLIOGRAPHY.

Garrison, Fielding H., Army Medical Museum, Washington, District of Columbia. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2–15.)

The Index Medicus for 1916 contains 830 pages as against 1,448 pages for 1913, 1,311 pages for 1914, and 1,011 pages for 1915, a loss of 618 pages (over 42 per cent) of bibliographical material in two years of the war period. The average annual loss from August 1914 to August 1917 is 537 pages or 37 per cent. The index for 1916 contains 152 pages as against 233, 215, and 170 pages for 1913, 1914, and 1915 respectively. German medical literature has not been fully accessible since the beginning of 1915, but through the courtesy of the American

Medical Association, the Boston Medical Library, and the New York Academy of Medicine a fair proportion of the German literature, in particular that in the weekly medical periodicals, has been indexed up to the end of 1916. The literature subsequent to this date will probably not be accessible until after the conclusion of the war. Apart from Germany, the only foreign nations which have kept up their full quota of medical literature are France, Italy, Spain, the Scandinavian and Spanish-American countries. The falling off of this material in England is evidenced by the fact that the British Medical Journal for the first half of 1917 contains 896 pages as against 1,440, 1,104, and 904 pages for the corresponding semesters of 1914, 1915, and 1916 respectively. A solitary Belgian journal, the *Archives médicales belges,* has been revived during the present year. The preponderance of war literature in the foreign periodicals is everywhere manifest.

BIOLOGY.

Morgan, T. H., Columbia University, New York. *Study of the constitution of the germ-plasm in relation to heredity.* (For previous report see Year Book No. 15.)

The program outlined in the application for the grant has been carried nearly to completion. The linkage relations of the genes of chromosomes II and III have been studied. The results for the second linkage group will be ready for publication this autumn; most of the data have been collected for the third linkage group and will be brought together in the course of the winter. Since publishing the report on the first or X chromosome (Carnegie Publication No. 237) much additional information on the location of as many more new sex-linked mutations has been collected.

The localization of the genes under "normal" conditions is only a part of the program followed, for in all three of these chromosomes inherited linkage variations have been discovered and studied. In addition to the inherited variations, evidence of the influence of external conditions upon linkage has been obtained by Dr. H. H. Plough, working as a collaborator. The possibility of differences in linkage relations existing in wild stocks from widely separated localities has also been looked into by another co-worker, Mr. A. M. Brown. A detailed biometrical study of crossing over has been carried on in the laboratory by Mr. J. W. Gowen; and an investigation of the relation between one crossover and a second in the same chromosome (coincidence) has been made by Dr. Alexander Weinstein.

In addition to these studies concerned directly with linkage, Miss Clara J. Lynch has carried on an investigation of certain unusual phenomena relating to fertility, and Miss Mary B. Stark has made a study of a sex-linked tumor that kills half the males in each generation. The researches of these six co-workers, while not subsidized by the grant of

the Carnegie Institution of Washington, are nevertheless direct outgrowths of the work done under the grant.

In the course of the work several unexpected and important problems have opened up; *e. g.*, the possibilities of dislocation within the linear series of genes either by "duplication" of sections of the series or by "deficiencies" of sections. These and several other related questions (various types of non-disjunction, etc.) are being attacked both by genetic analysis and by cytological examination.

Several hundred mosaics have been found; these may involve any one of the first three chromosomes, but are especially common for the first chromosome, where sex-characters are also involved (gynandromorphs). These mosaics bear directly on the questions of the distribution of the cleavage nuclei and of the independent differentiation of parts. They also furnish explicit data as to their own mode of origin.

New mutations in all the three large groups have continued to appear at an undiminished rate. As a result, the working material is continually being enriched, for new loci are becoming available for studies involving the use of linkage, more viable races are being substituted for poorer ones, and characters are arising that are more readily separable and that interfere less with the simultaneous classification of other characters. In addition to offering new means of approaching old problems, the new mutations are continually bringing in their train entirely new problems.

Finally, a great deal of time has been given to the question of the stability of the Mendelian genes. It has become evident that this problem can be most satisfactorily studied by means of linkage, and since *Drosophila* is the one form in which the linkage relations are thoroughly known, it is undoubtedly the best material for such work. Through the earlier work of Muller, Altenburg, and Dexter done in this laboratory, and through the intensive work of the last two years, it is now possible to demonstrate in the strictest sense the existence and Mendelian behavior of modifying genes. The immediate bearing of this demonstration on the problems of selection and of evolution is evident.

CHEMISTRY.

Davis, Paul B., Johns Hopkins University, Baltimore, Maryland. *Continuation of investigations begun under the direction of the late Professor Harry C. Jones on the conductivity and viscosity of electrolytes in non-aqueous and mixed solvents.* (For previous reports see Year Books Nos. 2–15.)

The investigations reported on here were carried out by the writer with the assistance of Dr. H. I. Johnson. Several problems begun under the direction of the late Professor Jones were completed and the results, together with those of other investigators (see Year Book No. 15), were prepared for publication.

The viscosities of cæsium salts in mixtures of glycerol with water were measured and the behavior of these compounds was found to be analogous to that of rubidium salts in such solvents, the cæsium salts, however, producing the greater lowering of the viscosity of the medium.

The work on the conductivity and viscosity of solutions of electrolytes in formamid as a solvent, begun several years ago in Professor Jones's laboratory, was brought to conclusion with the study of (1) a series of salts both organic and inorganic with a common anion, *i. e.*, nitrates and formates of the alkalis and alkaline earths; (2) a series of salts with a common cation, *i. e.*, the sodium salts of the organic acids; (3) a number of representative salts in mixed solvents containing formamid.

The results obtained for the conductivity of the salts with a common cation were compared with those already obtained in water as a solvent. It was found that while in general such salts have smaller conductances in formamid than in water, the dissociation at a given dilution is much greater in formamid. Some evidence was also found for the formation of solvates in the case of salts of the alkaline earths, their temperature coefficients being higher than for similar salts of the alkali metals. From viscosity data on these salts it appears that the anion remaining the same the viscosity increases with the degree of hydration of the cation.

Measurements of the conductivity and dissociation of salts of the weaker organic acids were limited by the small solubilities of most of these salts in formamid. It was found that the salts of monobasic acids have approximately the same conductance, while dibasic salts, being ternary electrolytes, have larger values. No evidence for the constitution of such salts was brought out by the conductivity data. The viscosity coefficients appear to increase with increasing complexity of the acid.

A number of electrolytes were studied in mixtures of formamid with ethyl alcohol. An increase in molecular conductivity was found to take place with increasing percentage of alcohol up to the solvent containing 25 per cent formamid and 75 per cent alcohol. The values pass through a maximum near that point, indicating an increase in the mobility of the ions.

The viscosities of mixtures of formamid and ethyl alcohol show but slight deviation from the normal values for binary mixtures, being

always somewhat less. The viscosities of solutions of salts in these solvents are always greater than those of the solvents themselves, the increments being less in the case of the non-hydrated salts of the alkalis than of the hydrated salts of the alkaline earths.

Morse, H. N., and J. C. W. Frazer, Johns Hopkins University, Baltimore, Maryland. *Measurement of the osmotic pressure of solutions.* (For previous reports see Year Books Nos. 2–15.)

Recently, the method of measuring osmotic pressure has been developed so that it is possible to measure the osmotic pressure of quite concentrated solutions. This method also greatly reduces the time which, heretofore, has been necessary to reach the equilibrium pressure of a solution. The results of this work by J. C. W. Frazer and R. T. Myrick, on "The osmotic pressure of sucrose solutions at 30°," have been published in the Journal of the American Chemical Society, XXXVIII, page 1907 (1916). During the past year this method of measuring pressures has been used in the investigation of the osmotic pressures of glucose solutions. Before undertaking this investigation it was decided to alter the apparatus in such a way that the solution could be stirred continuously, or at intervals, during the course of the experiment. One of the objects of this change was to ascertain if such agitation of the solution had any effect on the final equilibrium pressure or on the velocity with which this equilibrium pressure is reached. The results showed that agitation of the solution produced no difference in the final equilibrium pressure. No conclusion was reached as to the effect of agitation on the time required to reach the equilibrium pressure of a solution. This was probably because it was necessary to enlarge the capacity of the apparatus to accommodate the stirring device and there was consequently greater compression of the cell contents, necessitating a correspondingly greater intake of solvent through the membrane.

Measurement of the osmotic pressure of glucose solutions was undertaken to secure data over a wide range of concentration extending to saturation and at more than a single temperature. The work was begun by repeating the measurements on concentrations from 0.1 to 1.0 molar. The table on the next page summarizes these results on concentrations above 0.5 molar.

The measurements on concentrations up to 3.0 molar were made with glass monometers and with equipment described in the Journal of the American Chemical Society, XXXVIII, 1907 (1916); the measurements on the more concentrated solutions were made by the "resistance gage" described in the same publication.

The measurements were made at three different temperatures to obtain information on the influence of the heat of dilution on the temperature coefficient of osmotic pressure. The results are in general satisfactory and in accord with theoretical considerations.

The above results on the more concentrated solutions obtained by the "resistance gage" are not free from suspicion, since the gage coil has

constantly increased in resistance, and without subsequent recalibration of the coil it can not be said that its pressure coefficient has remained substantially the same.

Some work has been done on the osmotic pressure of electrolytes. Owing to the effect which this class of substances has on the colloidal nature of the semi-permeable membrane, the direct measurement of the osmotic pressure of electrolytes has not been possible. Efforts have been made to obtain protection of the membrane against this deteriorating influence. The most recent experiments along this line have been very encouraging. The substance which has been found to exert the greatest protective influence has little protective action on the class of suspensoids, and certain substances which have a great protective action on the suspensoids have apparently no influence in protecting the membrane against electrolytes. A more complete study of this question of protection of the membrane is very desirable.

Osmotic pressure of glucose.

Concentration, grams glucose per 1,000 grams water.	20°	30°	40°	Concentration, grams glucose per 1,000 grams water.	20°	30°	40°
89.4	.....	12.61	.....	345.1	.....	49.77	.....
107.2	.....	14.98	.....	346.8	.....	49.68	.....
125.2	.....	17.60	.....	362.1	.....	50.27	.....
143.0	.....	20 17	.....	436.1	58.41	.....	.....
160.9	.....	22.66	.....	439.7	58.79	.....	.....
178.7	.....	25.02	.....	430.8	.....	61.71	.....
263.6	36.00	.....	.....	439.7	.....	63.04	.....
263.6	36.02	.....	.....	411.1	.....	.....	58.90
265.3	.....	37.99	.....	429.0	.....	.....	61.34
265.4	.....	37.72	.....	504.0	68.60	.....	.....
253.8	.....	35.10	.....	527.3	.....	76.32	.....
353.9	47.49	.....	.....	530.9	.....	76.67	.....
355.7	47.60	.....	.....	539.8	.....	.....	77.11

Noyes, Arthur A., Massachusetts Institute of Technology, Cambridge, Massachusetts; and Throop College of Technology, Pasadena, California. *Researches upon (1) the properties of solutions in relation to the ionic theory, and (2) the determination of the atomic structure of crystalline substances by X rays.* (For previous reports see Year Books Nos. 2–15.)

During the past year the researches described in previous reports on the electromotive forces of voltaic cells and on the vapor-pressure of salt-hydrates have been continued, with the assistance of Mr. R. G. Dickinson. Especial attention has been given to the cell Hg + HgO, NaOH in water, $Cd(OH)_2$ + Cd, with the view of determining the free energies of cadmium oxide and hydroxide.

Much progress has been made, with the help of Dr. John B. Dickson, on a systematic recomputation of the free energies of the oxides, sulphides, and halides of silver, mercury, lead, and copper, based in part on data existing in the literature and in part on new measurements of electrode-potentials and of chemical equilibria made in this labora-

tory. Thus Mr. M. Chow has completed accurate determinations of the electrode-potentials of $Cu + CuCl, Cl^-$, and of $Bi + BiOCl^-, H^+ + Cl^-$, and Mr. E. Zeitfuchs of that of $Cu + CuI, I^-$. Mr. W. A. Felsing has determined the equilibrium conditions at 476° to 616° of the reaction $Ag_2S + H_2 = 2Ag + H_2S$, and Mr. E. S. Freed those of the reaction $Ag_2S + 2H^+ I^- = 2AgI + H_2S$ at 25°.

A systematic investigation of the atomic structure of crystalline substances by means of X-rays has been started, with the aid of Dr. C. L. Burdick, who had previously worked with Professor W. H. Bragg in London. With the aid of research funds appropriated for the purpose by each institution the expensive equipment required for this work has been installed both at the Massachusetts Institute of Technology and at Throop College of Technology, where it is expected to continue the researches through a series of years.

A study of chalcopyrite ($CuFeS_2$) has already been completed, whereby the location of the atom-lattices in this complex sulphide, crystallizing in the tetragonal system, has been clearly established, in a way which furnishes a further illustration of the interesting possibilities of this new method of science. This research will soon be published. A study of millerite (NiS) has also been nearly completed; and one on arsenopyrite (FeAsS) and another on the sulphates of barium, calcium, and lead are in progress.

Remsen, Ira, Johns Hopkins University, Baltimore, Maryland. *A problem in tautomerism.*

Some years ago I was engaged in an investigation on the constitution of the two tautomeric forms of the chloride of orthosulphobenzoic acid represented by the formulas $C_6H_4\left\langle\begin{matrix}CCl_2\\SO_2\end{matrix}\right\rangle O$ and $C_6H_4\left\langle\begin{matrix}COCl\\SO_2Cl\end{matrix}\right.$. These compounds can easily be obtained in any desired quantity in pure condition. Their properties are such as to adapt them to study. Inasmuch, therefore, as the phenomena of tautomerism are of great interest and our knowledge of the subject is very inadequate, and, further, as there is no other example of tautomerism that lends itself to investigation as well as this, I planned an extensive study of it. But my chemical activity was then seriously interfered with by the necessity of taking up another kind of work, and only a beginning was made in the prosecution of the larger investigation I had in mind. Interesting results were obtained and an account of these has been published.[1] The main conclusion drawn from these earlier experiments was that the high-melting chloride has the symmetrical formula $C_6H_4\left\langle\begin{matrix}COCl\\SO_2Cl\end{matrix}\right.$, and the low-melting chloride has the unsymmetrical formula $C_6H_4\left\langle\begin{matrix}CCl_2\\SO_2\end{matrix}\right\rangle O$.

[1]American Chemical Journal, vol. 18, 791; 30, 247.

This conclusion was based largely upon the results obtained by treating the two compounds with dry ammonia in solution in anhydrous ether. One of them gives the ammonium salt of orthocyan-benzene-sulphonic acid, $C_6H_4\left\langle\begin{matrix}CN\\SO_2ONH_4\end{matrix}\right.$, and the other gives the ammonium salt of benzoic sulphinide, $C_6H_4\left\langle\begin{matrix}CO\\SO_2\end{matrix}\right\rangle N.NH_4$. It seemed to me probable that the chloride which gives the ammonium salt of orthocyan-benzene-sulphonic acid is the one having the unsymmetrical formula, and that the one that gives the other product has the symmetrical formula. The connection is indicated thus:

$$\text{I} \qquad C_6H_4\left\langle\begin{matrix}CCl_2\\SO_2\end{matrix}\right\rangle O \longrightarrow C_6H_4\left\langle\begin{matrix}CN\\SO_2ONH_4\end{matrix}\right.$$

$$\text{II} \qquad C_6H_4\left\langle\begin{matrix}COCl\\SO_2Cl\end{matrix}\right. \longrightarrow C_6H_4\left\langle\begin{matrix}CO\\SO_2\end{matrix}\right\rangle N.NH_4.$$

Other reactions gave conflicting results, though those with aniline were fairly consistent and, so far as they went, these seemed to me to justify the conclusion drawn. In several cases both chlorides give the same product and sometimes these are symmetrical and sometimes unsymmetrical. With phenol, for example, both give sulphonphthaleïn, $C_6H_4\left\langle\begin{matrix}C(C_6H_4OH)_2\\SO_2\end{matrix}\right\rangle O$, which is unsymmetrical, while with benzene both give symmetrical products, either the diphenyl compound, $C_6H_4\left\langle\begin{matrix}COC_6H_5\\SO_2C_6H_5\end{matrix}\right.$, or the sulphon-chloride, $C_6H_4\left\langle\begin{matrix}COC_6H_5\\SO_2Cl\end{matrix}\right.$.

Later Dr. C. A. Rouiller, who was then my assistant, made the important observation that the high-melting chloride is transformed quantitatively into the low-melting when heated to 40° with aluminium chloride. This accounts for the fact that both chlorides give the same product when treated with benzene and aluminium chloride, for the temperature necessary to bring about reaction in this case is above that at which the transformation takes place. This raised the question whether different products might not be obtained from the two chlorides by using toluene instead of benzene, as toluene is more susceptible to the action of reagents than benzene. Further, it was thought that the temperature at which the reaction takes place might be lowered by working under diminished pressure, as was first suggested by Verley.[1]

The experiments with toluene were first carried out by Dr. M. B. Hopkins working with me. It was found that the high-melting chloride gives a product to which the formula $C_6H_4\left\langle\begin{matrix}C(C_6H_4.CH_3)_2\\SO_2\end{matrix}\right\rangle O$ must be assigned; while the low-melting chloride gives a sulphinic

[1] Bull. soc. chim. [3], 17, 206.

acid of the formula $C_6H_4\left\langle\begin{matrix}COC_6H_4.CH_3\\SO_2H\end{matrix}\right.$. While the evidence in favor of the formula given above for the product obtained from the high-melting chloride is not as clear as we should like, there is little room for doubt that the formula is correct. On the other hand, the evidence in favor of the formula of the product from the low-melting chloride is conclusive. It therefore appears that the conclusion drawn from the earlier experiments is wrong and that, as a matter of fact, it is highly probable that the high-melting chloride is the unsymmetrical one represented by the formula, $C_6H_4\left\langle\begin{matrix}CCl_2\\SO_2\end{matrix}\right\rangle O$, and that the low-melting chloride is the symmetrical one, $C_6H_4\left\langle\begin{matrix}COCl\\SO_2Cl\end{matrix}\right.$. The work of Dr. Hopkins all pointed to this as the correct conclusion. The details will be published later.

Next the investigation was taken up by Dr. J. H. Sachs, and his work was carried on during the academic year 1916–17. He studied the action of anisol and of phenol on the two chlorides in the presence of aluminium chloride in solution in carbon bisulphide.

With anisol the high-melting chloride gives the dimethylether of sulphonphthaleïn, $C_6H_4\left\langle\begin{matrix}C(C_6H_4OCH_3)_2\\ \quad >O\\SO_2\end{matrix}\right.$, while the low-melting chloride gives the sulphon-chloride represented by the formula, $C_6H_4\left\langle\begin{matrix}CO.C_6H_4OCH_3\\SO_2Cl\end{matrix}\right.$. These results again point to the formula $C_6H_4\left\langle\begin{matrix}CCl_2\\SO_2\end{matrix}\right\rangle O$ for the high-melting chloride, and to $C_6H_4\left\langle\begin{matrix}COCl\\SO_2Cl\end{matrix}\right.$ for the low-melting chloride.

When phenol and aluminium chloride are allowed to act upon the high-melting chloride in solution in carbon bisulphide two products are obtained. One of these is the compound $C_6H_4\left\langle\begin{matrix}C(OC_6H_5)_2\\ \quad >O\\SO_2\end{matrix}\right.$, the other is phenolsulphonphthaleïn, $C_6H_4\left\langle\begin{matrix}C(C_6H_4OH)_2\\ \quad >O\\SO_2\end{matrix}\right.$. The formation of both these compounds is in accordance with the view that the high-melting chloride has the unsymmetrical structure $C_6H_4\left\langle\begin{matrix}CCl_2\\ \quad >\\SO_2\end{matrix}\right.$. But now comes another one of those troublesome contradictions that made it so difficult in my earlier investigations to draw conclusions. The low-melting chloride, when treated with phenol and aluminium chloride in solution in carbon bisulphide, gives exactly the same products as the high-melting chloride!

This work should be continued and pursued in several different directions. The effect of temperature and pressure upon the course of the various reactions should be carefully studied, as also the effect of the nature of the solvent used. It is only by an elaborate study, such as I have planned, that anything like a clear view regarding the relation between the two tautomeric chlorides can possibly be gained.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. *Continuation of exact investigation of atomic weights and other physico-chemical properties of elements and simple compounds.* (For previous reports see Year Books Nos. 2–15.)

Although various causes contributed to diminish the amount of experimental work, several results of importance were obtained. The following investigations have been conducted during the past academic year with the assistance of this grant, employing permanent apparatus purchased with previous grants as well as with funds of the university.

Atomic weight of ordinary lead.

Sample.	$PbCl_2$ corr. to vacuum.	Ag. corr. to vacuum.	Ratio $PbCl_2$:2Ag.	Atomic weight Pb.
Pb	7.13723	5.53723	1.28895	207.187
Pb	7.60063	5.89675	1.28895	207.186
			Average...	207.187
Atomic weight of end fractions (A and B) of isotopic lead.				
A	3.70016	2.87854	1.28543	206.426
A	4.79633	3.73154	1.28535	206.409
A	4.64577	3.61412	1.28545	206.431
			Average...	206.422
B	4.64736	3.61568	1.28534	206.406
B	4.87838	3.79519	1.28541	206.422
B	4.68396	3.64425	1.28530	206.399
			Average...	206.409
Ag = 107.880. Cl = 35.459.				

1. Attempt to Separate the Isotopic Forms of Lead by Fractional Crystallization.

This research, which was a logical outcome of the earlier researches on the nature of radioactive lead, was partly carried out during the summer with the help of Dr. Norris F. Hall. Lead from Australian carnotite (believed to contain about 1 part of ordinary lead to 3 parts of radium G, with a mere trace of radium D) was fractionally crystallized over 1,000 times as nitrate and the end-fractions were purified

from the contaminations derived from the utensils used in crystallization. The atomic weights of the samples so obtained from the crystal (A) and the mother liquor (B) ends of the series, respectively, agreed within the experimental error of 6 parts in 100,000 parts of the chloride. The results are given in the preceding table, two control determinations of the atomic weight of ordinary lead being appended for comparison.

The β-ray activity of these samples was also studied with great care by means of an aluminum-leaf quantitative electroscope, having taken especial precautions to eliminate any outside source of ionization and to treat each sample in precisely the same fashion. The β-ray activities of the end samples were thus found to agree with one another within the experimental error of 1 per cent. Evidently, neither the atomic weight nor the ionizing power of the end fractions give any evidence that an appreciable amount of separation had occurred through the agency of the thousand crystallizations.

2. Melting-Points of Ordinary and of Isotopic Leads.

This investigation also was carried out with the help of Dr. Norris F. Hall. The comparison was made by means of a multiple copper-constantan thermocouple. Much time was spent in securing conditions as satisfactory as possible, but the results were not entirely definite, on account perhaps of the low latent heat of melting of lead. As a general average of 44 experiments by means of the cooling curve, a difference of 0.05° between the melting-points of the Australian radioactive lead and ordinary lead were observed, the radioactive lead having the higher melting-point. This difference was confirmed by differential measurements taken when each sample was partly melted. It is probable that the slight divergence was due to the fact that the ordinary lead was not of the very highest degree of purity, but it may have contained a trace of some unknown contamination. The lead from carnotite had been so completely purified as to leave no suspicion of this kind. In any case, the result, which we regard as merely preliminary, is enough to show that the difference between the melting-points of ordinary lead and radioactive lead is very slight.

3. The Thermoelectric Behavior of Isotopic Lead.

Dr. Norris F. Hall assisted also in this investigation, in which a sample of pure isotopic lead was placed in contact with pure ordinary lead and the junction treated as a thermoelement. No electromotive force whatever was thus developed. The electrical conductivity of the two samples have not yet been measured with a sufficient degree of accuracy to predicate complete equality of this property because of the difficulty of preparing a wire of even gage, but this matter will receive further attention.

4. Surface Tension.

Dr. Emmett K. Carver continued the work on surface tension and brought it to a stage at which further publication is desirable.

It has been shown that the finite contact angle, the one weak point in the capillary-rise method, does not exist with the liquids studied if the glass be properly cleaned and if evaporation of the liquids be prevented.

The correction for the capillary rise in the wide tube calculated by Rayleigh and Laplace has been experimentally verified.

An experimental curve for the capillary rise in tubes that are not wide enough to come under the mathematical equations has been obtained. This experimental curve fits smoothly between the theoretical curve for wide tubes and the theoretical curve for narrow tubes.

It has been shown that the method of calibrating tubes by weighing a mercury thread is not appreciably affected by a film of air between the mercury and the glass. The difference between capillary rise in air and *in vacuo* has been determined.

The surface tensions of water, benzene, toluene, ether, chloroform, carbon tetrachloride, and dimethylaniline have been measured. The surface tensions of the substances measured by Mr. L. B. Coombs in apparatus V have been calculated, using our experimental correction for the rise in the wide tube.

5. Melting-Point of Benzene.

This investigation, in the hands of Dr. Carver, continued an earlier research previously carried out with the help of Dr. J. W. Shipley. The object was the study of the effect of dissolved air on the melting-point of benzene. Without the correction for the effect of atmospheric pressure on the melting-point (0.029°), the difference in melting-point due to air was found to be −0.003°; with this correction the difference is −0.032°.

6. Standard of Temperature.

Dr. Victor Yngve, with the help of Professor Harvey N. Davis, of the Department of Physics, using the latter's very carefully prepared platinum resistance thermometers, compared the standard Baudin mercury thermometers employed for several years in the Wolcott Gibbs Memorial Laboratory with the platinum standard. They found evidence of a deviation from the probable thermodynamic basis similar in direction (although somewhat less in extent) to that found by Dr. T. Thorvaldson and mentioned in the Year Books 13 and 14. This study is to be continued, and when the temperature scale from 16° to 20° is finally established to within 0.001° in every part, a large quantity of thermochemical work can be computed and published.

Several of these investigations, as well as those mentioned in previous reports, have appeared in print during the current year, and are mentioned in the bibliography (pp. 36–46).

7. Solubility of Pure Salts as a Means of Fixing Points on the Thermometric Scale.

Of course any definite property of material possessing a marked temperature coefficient may be used to determine the thermometric scale. The solubilities of pure salts furnish suitable data, but since their changes with changing temperature are usually not linear, but are rather represented by curves, many solubilities must be determined in relation to the international standard in order to use these data for calibrating thermometers. Since no determinations of sufficient accuracy for this purpose seem ever to have been made, it appeared to be worth while to make a practical test by careful study of a typical case. Sodium sulphate was selected as one of the most suitable salts, for many reasons; and the work was carried out by Dr. Victor Yngve, whose work on transition temperatures had led to the suggestion.

It was found that the solubility of sodium sulphate is easily adjusted to exact saturation and is capable of precise estimation. Determinations of its magnitude at about 15°, 17.5°, 20°, 22.5°, and 25° were made with an accuracy which has perhaps never before been attained, referring the data to the Parisian hydrogen scale and to the platinum resistance scale. A fairly adequate empirical equation was derived, connecting temperature and solubility over this range, and the solubility values at degree intervals were computed. Although this was only a beginning, the results afforded a hope that in the future, when more data have been obtained, the method may be of real use to those who possess no accurate thermometer, by affording them a convenient standard of reference.

The experimental results, together with the extreme variations from the mean, recorded in terms of the temperature readings of two Baudin thermometers, carefully standardized at the Bureau des Poids et de Mesures, were as follows:

Temperature hydrogen scale.	Solubility $Na_2SO_4 10H_2O$ grams anhydrous salt per 100,000 grams H_2O
14.731°	12.925±0.001
17.472°	15.807±0.002
19.860°	18.866±0.005
22.265°	22.601±0.004
24.845°	27.468±0.003

Sherman, H. C., Columbia University, New York, New York. *Continuation of the chemical investigation of the amylases.* (For previous reports see Year Books Nos. 11–15.)

During the past year the investigations, referred to in previous reports, upon the chemical properties of pancreatic and malt amylases and also the amylase of *Aspergillus oryzæ*, have been continued.

In the study of pancreatic amylase attention has been directed to the problem of the exact nature of the relationship between the amylolytic and the proteolytic properties of our purified preparations of maximum power. This question has been investigated by means of purification experiments designed to obtain a concentration of proteolytic power. The method of purification previously reported has been varied in such a way as to secure further fractions of the material in which both proteolytic and amylolytic activities have been studied. The optimum hydrogen-ion concentrations for the proteolytic activities of preparations from the pancreas and from *Aspergillus oryzæ* have been measured and compared with each other and also with the optimum hydrogen-ion concentrations for their amylolytic activities.

In continuing the comparison of the three amylases the influence of the concentration of hydrogen-ion upon the activity of each was investigated. The experiments were so planned as to cover different concentrations of hydrogen-ion, ranging from $P_{+H}1.6$ to 10.4. The results thus obtained have established the points at which hydrolysis by the enzyme is prevented by acid and by alkali, and the concentrations of hydrogen-ion at which each enzyme shows its greatest saccharogenic power. These results are now being prepared for publication.

The rate of production of reducing sugar at successive stages of the hydrolysis of soluble starch by each of the three amylases is being studied in some detail.

Attempts at further purification of the amylase of *Aspergillus oryzæ* are being continued.

Smith, Edgar F., University of Pennsylvania, Philadelphia, Pennsylvania.
Investigations with the elements columbium, tantalum, and tungsten.

Dr. Walter Van Haagen is about completing a rather extended research on the atomic weight of boron and the atomic weight of fluorine. A report on the entire investigation may be ready about the first of October. A feature of this investigation is that the ratio between boron and five elements (the atomic weights of which have been well established) is determined with the greatest accuracy. Originally, it was intended to have Dr. Van Haagen work on columbium and tantalum, but it was thought desirable to finish the other work in hand when the grant was made by the Institution and submit the manuscript to the Institution.

ECOLOGY.

Clements, F. E., Tucson, Arizona. *Associate in Ecology.*

The field season of 1917 has been devoted to several of the larger problems in synthetic ecology. It was intended to spend the summer in completing the inquiry into the relation between present and past climatic cycles and the succession of plant and animal communities in Bad Lands, but in pursuance of the action of the Executive Committee of the Institution, it was decided to give the chief attention to grazing problems, expecially those dealing with carrying capacity and the consequences of overgrazing; this choice proved doubly opportune, owing to the drought prevalent throughout the grazing regions of the West and the critical situation arising out of the grazing homestead act. Furthermore, the general distribution of the open range agrees closely with that of Bad Lands, with the result that the work on the latter has been practically completed. While the lines of research are intimately correlated, they center upon five main problems, namely: (1) grazing, (2) indicator plants, (3) climatic cycles, (4) Bad Lands, (5) permanent quadrats.

Grazing Research.

Grazing conditions have been studied in northern Arizona, New Mexico, Colorado, northern Utah, Wyoming, northwestern Nebraska, western North Dakota, Montana, Oregon, and California. The major part of the work has been done on the open range and on private ranches, but considerable time has also been spent on the ranges of the National Forests. Particular attention has again been paid to the ecological studies carried on at the Utah Grazing Experiment Station, the Jornada Grazing Reserve, and the Santa Rita Grazing Reserve of the Forest Service, and at the Mandan Station of the Bureau of Plant Industry of the U. S. Department of Agriculture. A close scrutiny of the situation makes it clear that the grazing industry is in a critical condition throughout the entire West and that immediate action in accordance with the scientific results is imperative. It has proved possible to construct a new and practical system based upon the intensive quadrat studies of the several reserves and the extensive investigations of the summer. This rests upon five cardinal points, namely: (1) classification, (2) protection, (3) utilization, (4) plant introduction, (5) cooperation; it will be treated in detail in the monograph on indicator plants and vegetation.

Indicator Plants.

The recognition and use of plants and plant communities as indicators constitute an outstanding problem in synthetic ecology which has been almost wholly neglected. It is based upon the fundamental fact

that the plant is necessarily the best measure of optimum conditions for its growth and reproduction. As a consequence of its association with other species in definite communities, it serves as an index to the possibilities of both soil and climatic areas. When the successional position of an indicator has been determined, one can not only predict what plants and communities will follow it naturally, but can also determine what plants will enter in consequence of overgrazing, fire, lumbering, etc. It is the successional significance of a dominant species which makes the use of indicators so indispensable in grazing and in forestry. When the presence of an indicator is checked by the number and size of its individuals, a scale of extreme sensibility is obtained, on which it is possible to read accurately the variations of one year and to forecast with certainty those of the next. Moreover, by the correlation of dominants with the physical factors of the environment, and especially the determination of their water, light, and temperature requirements, they may be used as crop indicators, particularly in dry-farming operations. Grazing indicators have naturally received the most attention during the present summer, but this has necessarily involved a study of dry-crop indicators as well. The succession research of the preceding four years and the quantitative study of habitats and dominants at the Alpine Laboratory from 1900 to 1912 have produced a large amount of material on forest indicators especially; this has been checked by spectrophotometric observations during the present summer, and it is hoped to present the combined results in a manuscript available in December.

Climatic Cycles.

The most attractive and promising feature of the summer's work has been the tracing and checking of the course of the present climatic cycle. The second recorded absolute minimum of no sun-spots occurred in 1913, and served as the focus of a period of exceptional rainfall in the West. The drought of the present summer in the Western and Mountain States suggests the beginning of the dry phase of the cycle. Its effect upon the carrying capacity of the ranges and upon the production of dry farms has been critical. Whether it be followed by the full period of several dry years or not, it has furnished further confirmation of the fact that all grazing and dry-farming must be based upon the recurrence of dry periods; in both, a scientific system of expansion and contraction must be devised to prevent disaster during dry years. If the next two or three years prove to be dry in harmony with the maximum of the sun-spot cycle, the possibility of anticipating dry seasons will be greatly enhanced. In the field of forestation much evidence has been obtained to show that planting is successful only during wet phases and that natural reproduction occurs practically only during such phases. It is obvious that no other scientific advance will mean

more to the country and the world at large than the conclusive demonstration of the coincidence of sun-spot cycles and climatic cycles. For this reason a large part of the winter will be devoted to a further scrutiny of the astronomic, climatic, and biotic evidence of such cycles and their incorporation into an ecologic system. In particular, it is proposed to obtain new evidence by establishing cyclic series of permanent quadrats in grassland and forest and to extend these as soon as possible to field crops. This will determine conclusively whether there is a sun-spot climatic cycle of sufficient intensity to control plant production under cultivation as well as in nature.

Climatic Cycles and Succession in Bad Lands.

Bad Lands afford a unique field for studying the succession of plant and animal populations and the correlations of the latter with major climatic cycles. Present-day succession in Bad Lands has now been investigated in 75 localities and 12 States and a large amount of geologic and biotic material has been obtained. During the summer especial attention has been given to the alternating horizons of shale, sandstone, and conglomerate in 20 bad-land formations from the Permian to the Miocene. It has proved possible to use alternating deposition as a measure of cycles of erosion and climate on the uplands and hence to give a much more complete picture of upland life than hitherto. With the generous help of Dr. Knowlton, of the National Museum, and of Dr. Matthews, of the American Museum, graphic compilations have been made of the distribution of plants from the Permian to the Pleistocence and of animals throughout the Tertiary. Dr. Hay, of the Carnegie Institution of Washington, has kindly offered his records of Mesozoic and Pleistocene animals for the compilation of similar tables. As a consequence, it is hoped to obtain a number of new correlations, which will throw additional light upon the connection between climatic cycles and life cycles. Incidentally, the question of reclaiming Bad Lands has received some attention; since they cover many thousands of square miles, even their partial reclamation for grazing purposes will prove of much importance.

A System of Permanent Quadrats.

In working toward the basic correlations involved in synthetic ecology, it has long been felt that the use of selected areas to determine changes of population from year to year is imperative. In no other way can accurate and conclusive evidence be obtained as to the effect of climate and soil upon plant and animal communities. If carried through the eleven-year period of the sun-spot cycle, a series of such permanent quadrats will furnish final evidence as to the existence of a corresponding cycle in climate. On the practical side, it will prove invaluable in tracing the fluctuations of carrying capacity on the range, of

regeneration in the forest, and of crop production in arid and semi-arid regions. As a consequence of earlier recommendations, the Forest Service has already established a large number of permanent quadrats at its experiment stations and grazing reserves. It is now proposed to incorporate these into a definite system for obtaining annual evidence as to the direction of climatic movement and its effect upon the various types of communities. Such a climatic series will require the establishment and charting of at least one permanent quadrat for each year of the cycle. In this way an actual record will be made of the yearly changes of population for the entire period, while the annual charting of the quadrat established will afford a complete picture of the changes in one spot. Certain quadrats will be grazed, cut, burned, or denuded and will thus furnish detailed evidence as to variations in carrying capacity or crop production as well as to the invasion of less valuable species in the case of overgrazing or denudation. Quite apart from their climatic and economic value, such quadrats will prove invaluable as an experimental record of succession. It is hoped to establish climatic series of quadrats on the National Forests and at the experiment stations and substations of the Western States as rapidly as possible. Some important areas, especially in Bad Lands, dunes, swamps, and saline basins, can not be handled in this way. It is expected to locate and chart these in connection with plans now being matured for doing the basic experimental work in synthetic ecology at the Alpine Laboratory at Pike's Peak and for carrying the results out in extensive fashion into the climax grasslands and forests of the West.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2–15.)

In my last report of progress (Year Book No. 15, pp. 358–359) a purpose was expressed to limit further cosmogonic studies, at least for the present, to a report on such collateral work as had been undertaken incidentally in the search for the genesis of the earth—on which reports have already been made— and to devote future studies to problems closely related to the earth itself, particularly questions relating to the major dynamics of earth-shaping and to the climatic states of the geologic ages. This purpose has controlled the work of the year in the main, but not entirely. A new phase of cosmogonic inquiry has grown out of the recent success of observers in the measurement of the velocities of nebulæ, and this has seemed to make a further study of nebular theories advisable.

While the velocities of only a small fraction of known nebulæ are as yet determined—and these determinations are to be held in some measure tentative—the results leave little room for doubt that the mean orbital speeds of nebulæ are notably greater than those of stars. This does not apply equally to all classes of nebulæ, but has significance in two of the four leading classes: (1) Certain nebulæ, and certain vague nebulosities scarcely well enough defined to be called nebulæ, seem to be so physically connected with certain stars or star-clusters that they must be regarded as having essentially common velocities. (2) Certain nebulæ whose forms suggest an origin by collision have low velocities. (3) Planetary nebulæ that seem to be free from bondage to stars or star-groups have velocities whose mean is about seven times as great as that of the blue stars[1] to which they are nearest in spectroscopic character and presumably in evolution. (4) Spiral nebulæ, so far as determined, disclose a mean velocity twenty or thirty times as great as the mean velocity of white stars to which they seem spectroscopically most nearly related. Probably a closer discrimination of classes will be required when velocities are more generally determined, but the data already acquired call for inquiry into possible sources of enhanced nebular velocity and the significance of such velocity in evolution.

The Revived Herschellian Hypothesis.

Incidentally, the disclosure of the high velocities of spiral nebulæ has stimulated a reconsideration of the view of the elder Herschel that nebulæ are merely dim, distant star-clusters of the order of our galactic system. Of course, the bright-line nebulæ are omitted from

[1] W. W. Campbell, presidential address before the American Association for the Advancement of Science, delivered in the American Museum of Natural History, New York City, Dec. 26, 1916.

the resuscitated Herschellian hypothesis. Every additional working hypothesis is a gain, and a competitive hypothesis of the origin and dynamics of spiral nebulæ should be specially serviceable in stimulating observation and in drawing forth a critical interpretation of results. The working hypothesis elaborated in connection with these studies, based on dynamic encounter incidental to close approach—first put forth in 1901[1] and re-stated in greater detail in Year Book No. 3, 1904, pp. 208–219—has heretofore been rather lonesome in its field and should profit by competitive companionship.

As specifically pointed out in the Year Book just mentioned, the assignment of the origin of spiral nebulæ to dynamic encounter is not a necessary part of the planetesimal hypothesis, the chief theme of which is the origin of *planets* rather than nebulæ. In so far, however, as an evolution of planets involves a nebula, an interpretation of the origin of the nebula is necessary to carry the evolutionary process back through an appropriate cycle to what may be regarded as an original or an equilibrium state, the more so because a nebula gives no signs of being in such equilibrium state; its form rather distinctly implies that it is in a transitional state, if not a nascent or juvenile state. If the partial revival of the Herschellian view—limited to the white nebulæ—is to serve as an effective working hypothesis in any other than a formal sense, it needs specific development on its genetic side, as also on its dynamic side, for the spirality of these nebulæ seems to imply a specific genesis actuated by distinctive dynamics. It has been a part of the work of the year to endeavor to see how far the doctrine of dynamic encounter by close approach can be associated with the revived Herschellian view so as to give it appropriate genetic and dynamic qualities.

As heretofore set forth in these studies, the hypothesis of close approach has been deployed in little more than its *planetary* relations, but it is obviously applicable to higher orders of organization. If a cluster of stars, of any order, passes near another such cluster, or penetrates it eccentrically, a spiraloidal effect seems inevitable. It would seem that dynamic encounter might at least serve as an adequate agency for the generation of such obscure spirality as that of our own galactic system, and that of the Magellanic clouds, if indeed they are really spiraloidal at all. It remains an open question, however, whether a star cluster would be thrown by such encounter into an extended, two-armed, sharply defined spiral deployment, such as constitutes the most declared type of spiral nebulæ.

The main reason for doubting the competency of dynamic encounter to produce the highly deployed two-armed spirals lies in the apparent absence of a special deploying force, bilaterally controlled. In the planetary application of dynamic encounter set forth in these studies

[1] Astrophysical Journal, XIV, 1, July, 1901, pp. 17–20; Jour. Geol., IX, 5, July-Aug. 1901, pp. 369–393.

such a bilateral decentralizing force is assigned to the explosive energy of very eruptive stars when stimulated and supplemented by the cooperation of tidal elongation. With this combination of tidal and explosive action, the resources of dynamic encounter appear competent to give a very wide deployment to giant suns when the approach of the two bodies is very close. There is reason to think that clusters of germ-suns, some thousands in number, may arise from such cooperative agencies when the stars are very massive; but without this eruptive factor it is not clear that even the utmost resources of dynamic encounter are adequate to give to great star systems, already widely deployed, more than a spiraloidal deformation. But it is worth considering whether the very great deployment previously attained may not replace the explosive factor in the planetary case, for such deployment gives great efficiency to the differential effects of tidal action.

As already remarked, the *forms* of spiral nebulæ seem clearly to imply an active *transitional* state. Spiral nebulæ seem to be about as far as possible from an ideal equilibrium or final state, or any measurably permanent state referable to Newtonian mechanics. In contrast with this, equilibrium states of a high order of maturity seem to be represented by the eighty-odd globular clusters that form subfeatures of our galactic system. These globular clusters imply that the age of our stellar system is so great as to have given time for the evolution of steady states of interaction in stellar assemblages vast enough to embrace tens of thousands of stars. Such mature organizations equally imply the effective and protracted working of the law of partition of energy resulting in an appropriate distribution of velocities and of orbital dimensions and attitudes. Now, if spiral nebulæ are to be interpreted as dim, distant star-clusters of the highest order, "island universes," comparable to our whole galactic aggregation, and if the generalization that most of the white nebulæ have the spiral form is also to be accepted, the revived Herschellian hypothesis seems forced to carry the corollary that most of the stellar "universes" *are as yet scarcely past their infantile states.* Even if only the majority of white nebulæ are spiral, the corollary has much significance. It is, under this interpretation, quite remarkable that so few of the nebulæ interpreted as star-clusters show by their forms more than the very earliest steps toward a steady state of star aggregation such as should be evolved in time under the law of partition of energy. This is the more remarkable since the law of partition of energy is so beautifully expressed in the globular clusters. To interpret all the white nebulæ as star-clusters seems thus to carry implicitly the very radical question, How can such singular and seemingly nascent states of organization have arisen in so large a proportion of all the observable aggregations of this major class? This in turn raises, in a very acute form, the question whence comes an adequate frequency of action—whatso-

ever the agency—to give rise to these juvenile forms affecting so many of the highest order of known organizations. The immediate problem in hand, the rehabilitation of the Herschellian hypothesis by such help as dynamic encounter may offer in such deployment, raises the special question whether appropriate encounters between galactic systems can occur often enough to maintain, in proper proportion to the whole number of aggregations susceptible of such interaction, the observed number of spiral forms.

Before emphasizing the unpromising aspect of the question put in this form, it is worth while to consider the subconscious concepts likely to lurk beneath such a question and to vitiate its answer. An analogous question has been raised relative to the adequacy of close approach of stars within our galactic system to give the observed supply of nebulæ assigned to close approach.

(*a*) The immense extension of knowledge of celestial space, forced by progressive observation, has also forced the conclusion that collisions and close approaches are far apart. No equally imperative force has deployed our concepts of *time* in like degree. On the contrary, the old speed-concepts of evolution have largely lingered and have introduced incongruities into current concepts of time in its relations to concepts based on space. As a matter of fact, consistent concepts of evolution—especially adequate concepts of the evolution of great star organizations, "universes" in our inherited phraseology—clearly require enlargements of our working concepts of the lifetime of clusters, of stars, and of nebulæ to a degree comparable to the enlarged concepts of space forced by observation. Such a parity of concepts, when realized, removes almost the whole cogency of the challenge of adequate frequency, so far as planetary genesis is concerned. If there are 150,000 nebulæ in our stellar galaxy and 150,000,000 suns susceptible of becoming producers of nebulæ by close approach or collision, it is necessary only that a nebula should live one-thousandth of the generation interval to keep the supply of nebulæ up to the present figure. The question of adequacy hangs as much on the longevity of the nebulæ as on the rarity of close approach. An analogous revision of time concepts gives some relief at least to the much more formidable challenge of the adequacy of close approach or penetration to give a spiral state to the hypothetical star systems supposed to masquerade as white nebulæ. The high velocities, the powerful attractions, and the vast expanses assigned the star-clusters under this view, favor frequency of interaction, when frequency is measured in appropriate terms based on the life-period of a disturbed galactic state.

(*b*) If our galaxy has recently been disturbed, let us say by the penetration of the Magellanic cluster, the assumption that the present is a normal state in respect to the number of nebulæ is scarcely warranted. The galaxy is presumably passing from its disturbed state

toward one of mutual adjustment and equilibrium. The present number of nebulæ may thus represent an inheritance from the greater prevalence of conflicting action in the past.

(*c*) Those who have expressed adverse views as to the adequate frequency of collision and close approach to rejuvenate planetary systems appear to have confined themselves to one phase of the problem, the statistical probability of approach when only velocity and space are considered. The considerations that weighed most in the formation of the theory of close approach[1] have been largely neglected. A theory is entitled to the benefit of its own postulates and is not responsible for assignments that replace these. It is not believed that the true frequency of approach can be determined, or even fairly estimated, by dealing simply with inherited velocities under observed conditions of distance and direction in one part of the galaxy; it is the postulate of the theory that mutual attraction, as well as the several types of spacial relations and motions in a normal star assemblage, must enter into any estimate that is entitled to weight. If inherited motions and space relations prevalent in this part of the galaxy alone are considered, the liability of stars to close approach will doubtless be essentially as urged, but if the mutual attractions of stars (especially under the favorable condition of sub-parallel motions held to prevail in a large part of the galactic system) are considered, the inquiry takes on a different aspect. The law of partition of energy applied to an assemblage of bodies moving initially at random among one another assigns to the inner bodies courses that traverse diversely the centroidal region, while courses more largely sub-parallel prevail in the outer zone of the assemblage.[2]

A numerical inspection of the relative influences of inherited motions on the one hand, and of concurrent attractions on the other, made at the time of preparing the original statement of the theory of disruptive approach, in 1901, led to the intimation that the spacial and velocity relations in this part of the galaxy had approached a stage of evolution such that disruptive approaches were near a minimum and that either notably higher velocities or notably lower velocities would increase the number of disruptive approaches. This intimation was given weight, and led to assigning to different zones of the galaxy different degrees of productiveness of nebulæ. Subsequent studies have led to a theoretical distribution of the sizes and kinds of nebulæ. Some such differential assignment seems essential in the interpretation of the different classes of nebulæ that are being revealed by progressive observation.

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[1]See original paper, Astrophysical Journal, July 1901, pp. 38–39.

[2]Compare the discussion of the motions of molecules in the atmosphere, Chapter I, The Origin of the Earth, The University of Chicago Press, June 1916.

See also "The bearing of molecular activity on spontaneous fission in gaseous spheroids, Tidal and Other Problems," Carnegie Inst. Wash. Pub. No. 107, 1909, pp. 163–167.

Though the stellar galaxy shows signs of a disturbed distribution of stars and star-motions, it presumably conforms in a general way to the state of equilibrium normal to an oblate spheriod of stars of initial random motion, coordinated with the motions implied by its oblate form. Assuming this, there should be (1) a common sphere of control for the whole assemblage, whose form should be an oblate spheroid conformable to the general configuration of the galaxy itself, and (2) special spheres of individual control for each star, nebula, and other body within the galaxy, all of which sweep in individual orbits through the enveloping galactic sphere of control. These spheres of control represent the dynamic concentration of gravitative influences that condition the deployment of nebulæ regarded as products of dispersion. It is a corollary of this postulate of the centralized arrangement of gravitation that the extent of the sphere of control of any star—or other body—will be determined in part by the position of such star in the enveloping sphere of control of the galaxy, and in part by the relations of the spheres of control of neighboring stars to it. It is also a vital part of the corollary that the deployment of a star—or other concentration of matter—into a nebula by dispersion must conform to the forces of generation in so far as the field of deployment lies *within* the sphere of control of the parent body, but that, so soon as the dispersion passes beyond the border of such parental sphere of control, it is subject to distortion and to possible destruction by the gravitative influences of neighboring spheres of control or of the enveloping sphere of control of the galaxy.

There are intermediate orders of enveloping spheres of control, but they need not be brought in here to complicate the case. It is sufficient here to note that the development of a nebula of definite form is radically dependent on the sphere of control within which it is generated. Beyond such sphere it is likely to be distorted, if not dissipated.

1. Now, if our galactic system approaches the consistent organization assigned to it, the spheres of control of its constituent stars will, as a rule, be smallest in the zone of greatest galactic attraction, and hence in that zone systematic nebular deployment from a given star is most restricted. Moreover, the restricted nebula there formed should—other things being equal—pass most rapidly on in its evolution from its initial state toward its later states. This zone of maximum galactic attraction is thus likely to take on a relatively barren aspect so far as nebulæ are concerned. Great symmetrical nebulæ, like the giant spirals, are essentially incompatible with the conditions of genesis that prevail in this zone. Small spiral nebulæ with dimensions confined to the restricted spheres of control of the parent stars should find free conditions of deployment in this zone, but they would be under stress to pass promptly from their distinct spiral form into a discoidal form.

2. In the centroidal region of the galaxy the individual spheres of control of stars grow larger in proportion as the centroid is approached,

when such spheres are not deformed by the encroachment of the spheres of the abundant neighboring stars of that region. Larger and freer deployment is there permitted, as also a longer life. The centroidal tract should, to this extent, be richer in nebular development than the zone of maximum gravitation that lies outside it, and this seems to accord with observation. But even here the limitations are severe and very large nebulæ of any symmetrical or systematic type are practically inhibited, chiefly by the encroaching individual spheres of control that traverse the region. Irregular nebulæ, especially those of incongruous distributions of matter, together with vague nebulosities that scarcely show any organization at all, are consistent with the dynamic conditions that prevail in this centroidal region.

3. Outside the zone of maximum galactic gravity, the individual spheres of control increase gradually in volume to an indeterminate extent. Theory requires that an occasional star—very rarely indeed—shall be shot away from the galaxy at a velocity beyond its control. The individual sphere of control of this "runaway" star would then grow in dimensions indefinitely as it passed away, if it did not encounter some unknown sphere of control outside our galactic system. It is important here only to recognize that, in the outer part of this sparse zone, the spheres of control of stars would almost certainly be large enough for the deployment of even giant spiral nebulæ, under the view that they are star deployments or deployments of sub-clusters of the galactic system. It is to be noted further that here systematic nebular developments would find their greatest freedom from distortion. And so, also, the endurance of nebulæ in this outer zone should reach an order of value far beyond that assignable to any form of nebula generated under the conflicting conditions that dominate the denser part of the galaxy.

In the main, the orbits of stars in this outermost zone should, theoretically, be either the outermost loops of very extensive ellipses whose inner loops traverse the denser part of the galaxy, or else broad enveloping ellipses that encircle the whole galaxy. In either case the inherited velocities are habitually low, sub-parallelism abounds, and mutual attraction has a relatively free field. Very close approaches and very wide typical deployments are favored. The sparseness of stars in this region renders close approaches due simply to inherited movements very rare, but the effectiveness of mutual gravity should render the ratio of close approaches comparatively high for such degree of sparseness and the nebulæ should be relatively large and lasting. This is the zone to which giant spiral nebulæ are assigned.

Spiral nebulæ formed in the interior of the galaxy are, as already noted, necessarily small and evanescent as observable spirals. Their secondary forms are to be sought among the small nebulæ that give evidence of some advance in evolution. Certain small nebulæ give hints of spirality or of knotty structures, perhaps assignable to a spiral ancestry. Of the small nebulæ in the denser part of the galaxy, com-

monly styled "gaseous," only a portion exhibit such a systematic distribution of luminosity as to imply a true gaseous organization in the recognized physical sense. The peculiar distribution of matter in these small nebulæ, so far as such distribution can be judged from luminosity, awaits dynamic study as fast as the requisite definition becomes available. Meanwhile, it is unwise to rest much on their "gaseous" nature. Their spectra imply *free molecules*, indeed, so charged that they are luminescent, but the dynamic control of these free luminous molecules is, in most cases, as much a problem yet to be solved as if they were small aggregates of matter in other than molecular states. Probably nothing can be safely regarded as really gaseous that does not conform to the laws of distribution of true gases.

The foregoing analysis of the assigned conditions of genesis of nebulæ bears definitely on their distribution, and only a few words are needed to make clear their bearings on the alternative views of the nature of spiral nebulæ offered respectively in behalf of the revived Herschellian hypothesis and of the earlier hypothesis of dynamic encounter. The former places the star-clusters that masquerade as nebulæ far out in space in positions in no assignable way dependent on our galactic system. Their mean distances are presumably about equal in all directions. With equally good seeing in all directions, no specific localization is assignable.

The hypothesis that the nebulæ are dispersed stellar matter places the large spiral nebulæ in the open outer zone of the galactic system, concentric to its denser part. They thus vary greatly in distance from our point of observation; those in the outer zone beyond the rim of the denser galactic disk may be ten times as far from us as those at the sides of the disk.

Under the Herschellian hypothesis the intrinsic light of the star-clusters is great; their dimness depends on distance. At such great distances the gradient of diminution of light is very low and great differences in remoteness are required to produce a given degree of dimness, if clear seeing is assumed. Under the alternative view, the intrinsic light of the nebulæ is relatively low, their dimness being due as much to this as to remoteness. At the shorter distances to which they are assigned, the gradient of diminution in luminosity is higher and lesser differences of distance yield a given diminution. It is thus not unreasonable to believe that such differences of distance as the placements under this hypothesis postulate may mark the change from visibility to invisibility.

In so far as intervening matter is a cause of invisibility, both views stand on essentially the same basis, except that a *combination* of greater distance with increasing intervention of matter is more available for the latter than for the former.

Sources of High Nebular Velocities.

In respect to velocities, the Herschellian hypothesis has the tactical advantage of a free field, since nothing is known, independently, of the normal velocities of "island universes," except perhaps in the putative case of the Magellanic clouds that play a part in both hypotheses. On the assumption that the clouds and the galaxy have recently been at their peri-galactic point, both should have acquired in their previous approach velocities much higher than is normal to their class, as well as higher than they will come to have later as their present mutual backward pull continues its effects. By assigning a high value to the latter, interpretation might possibly reverse the apparent support this case lends to high velocity as a prevailing quality of great star systems. The following considerations are thought to bear on nebular velocities:

A. The law of partition of energy among bodies moving diversely among one another assigns the higher order of velocities to the less massive bodies. If this could be applied without qualification, it would seem to offer a presumption against assigning the highest order of velocities known in the heavens to the most massive organizations; but the application of the law in this case perhaps does not hold, for lack of a proper basis of reference from which to measure velocities. Velocities, as now measured, would take on enhanced values if referred to a standard representing the motion of galactic systems.

B. If the spiral, planetary, and other definite nebulæ consist of highly dispersed matter deployed from stars or other aggregates, by collision, disruptive approach, or any analogous agency, a special enhancement of velocity in the nebular product above that of the parent body seems requisite to meet the new disclosures of high nebular velocity. This constitutes an imperative problem. The main studies of the year in cosmogonic lines have been given to this problem in the form of an inquiry into possible sources of such enhancement. The study, however, runs back for several years. The mode of inquiry was chiefly graphic, but the following simple statement may suggest its essence:

Giant nebulæ are naturally attributed to the dispersion of giant stars. The agency of their deployment is assigned to the powerful interaction of their great masses as they pass very near one another at very high velocities. These high velocities are chiefly assigned to *mutual attraction* under the conditions previously sketched. The stars may not be more than a few radii apart when they pass one another at periastron. The velocities acquired in such very close approaches of very massive stars would, in the higher order of cases, considerably exceed the highest velocity as yet determined for any nebula. The vital issue, however, lies in the conditions that control the motions of the two masses after their closest approach is passed, for mutual attractions are then reversed. If the stars, after passing one another, remain

in the same form as before, their mutual backward pull will reduce their velocities approximately to their former velocities, save for some interchange due to partition of energy. The algebraic sum of their moments of momentum must be preserved, but as this algebraic sum is the difference of the momenta of the two stars, it is consistent with a wide range of individual velocities offsetting one another. The critical question, therefore, lies in the effect which the deployment due to the eruptive projection of some large part of the star-masses will have upon the velocities of the newly formed nebulæ as they, in place of the stars, retire from one another. According as there may be any degree of reduction of the backward pull, an enhanced velocity, compared with the normal star velocity, will be retained.

The simplest line of inspection may be made clear by an appeal to general principles, as follows: (1) In so far as the stars remain spherical during the whole history of the interaction, no effect (other than the normal partition of energy) will follow; (2) in so far as elongations and projections are developed, and these are directed in the line of mutual attraction of the stars, or dominantly referable to it, the gravity effect will be increased; (3) in so far as the axis of such elongations and projections is dominantly transverse to the line of mutual attraction, the gravity effect will be reduced.

Now in all the earlier stages of approach, the lines of elongation and projection will diverge from the lines of mutual attraction by a small angle only, and hence tidal elongation and eruptive projection will increase the velocities of the approaching stars. The early stages of the assigned deployment thus add to the high velocities of approach against which drafts are to be made later by backward pull after periastron is passed.

But near periastron the courses of the stars are sharply curved into directions largely transverse to their previous courses and the gravity effect of elongation and projection is reversed. New projections should continue to take place until periastron is passed, unless the expansiveness of the stars has been exhausted previously. These projections will, like the previous ones, be directed, as they start forth, in the changed line of attraction, but they will quickly be brought into a transverse attitude by the swift motion of the stars at this climacteric stage. Some lag in the eruptions at all stages must be presumed, so that the transverse attitudes will be delayed and will tend to fall mainly after periastron is reached—*i. e.*, they will fall in the stages in which mutual attraction retards the previously acquired velocities. In so far as they thus reduce the backward pull they leave the nebulæ, in passing on, a larger portion of the velocities previously attained.

After the stars have swung about one another and begin to pass away in nearly opposite directions, their attitudes toward the projections are again reversed except as rotation or revolution has intervened to change these. While the rotation or revolution of the projected matter greatly complicates the case, it appears that each couplet of

projections must pass through attitudes that alternately increase and decrease the attractive force. The more effective attitudes of increase will fall before periastron and enhance the acquired velocities, while the more effective attitudes of diminution fall after periastron and reduce the effect of the backward pull. The chief effects, so far as intensity of gravity is concerned, are those that arise close about the passing of periastron. It appears, then, that the great resources of internal repellancy in the stars is so expended in the dispersion of the constituent matter as to diminish the restraining effects of backward attraction, and so to leave the nebulæ in the possession of a larger percentage of the high velocities attained in their approach than they would have held if they had remained in their undispersed state. In this statement both stars are assumed to be dispersed. Both will, by hypothesis, be subject to dispersion, but the degree of dispersion is supposed to be chiefly dependent on the degree of eruptivity of the stars, which is liable to vary greatly.

C. A second possible source of high nebular velocity is assignable to electric dissociation. When the normal conditions of stars prevail, the proportion of neutral electric states so vastly overwhelms the dissociated states that the effect of the latter is regarded as negligible. Even if dissociation were to go far, in the normal state of aggregation, the positive and negative elements (so long as confined to the stellar globes) would be so near together as to neutralize one another, in effect, so far as their relations to distant bodies are concerned. But in the case of the assigned nebular dispersion the conditions are sufficiently unique to require special consideration. The inquiry has proceeded on the basis of the following propositions:

(1) The positive nucleus is less often detached from its atomic associations than is the electron; (2) when detached, the electron moves at a greater mean velocity than the positive element; (3) when free, both positive and negative elements move at velocities greatly beyond the power of gravitative control of any star or cluster of stars; (4) when dispersion permits ready escape, the negative element surpasses the positive in radial discharge until the tension developed shall become great enough to restrain its superior tendency to escape or to compensate it by increased counteraction.

It is reasoned that this primary tendency to wide differentiation in space, and the succeeding tendency to neutralizing counteraction, would lead to an alternating concentric zonal distribution of the electric states, in which the series of positive zones would center and have their maxima in the great aggregates of matter whence they would die away progressively, while the alternating series of negative zones would have their relative dominance in reverse order; the two would thus form an interacting series which, coupled with the originating projections, would form a cycle, ever renewing itself by projectile action and ever reneutralizing itself by counteraction.

On this basis it would follow that, in proportion as any assemblage of matter looses an excess of electrons and thus becomes dominantly positive at center, it repels any similar positive assemblage. To the extent of its value, this repulsion should offset an equivalent amount of gravitative attraction, whatever the ultimate nature of that attraction may be. In the normal stellar state this, as remarked already, is regarded as negligible, but it may plausibly be assumed that, in the vast deployment of a star into a spiral nebula, there would be an unusual amount of electric dissociation, and further that the vastness of the deployment would enormously increase the facilities for the escape of electrons. In this case the remnant positive charges of the two dispersed bodies would offset a larger fraction of mutual gravitation than if the stellar matter had remained concentrated as before in spheres. To the degree that electric repellancy was thus developed between the deployed nebulæ, the restraint of the prodigious velocities acquired in approaching periastron would be neutralized and correspondingly higher velocities would be retained.

4. Still another possible source of high nebular velocities may spring from radiation pressure. So long as stars remain essentially spherical, the radiation pressure which they exert upon one another is very small compared with their mutual gravitation. If, however, stars are explosively scattered into nebulæ, it seems eminently probable (1) that the radiation sent forth from them would be greatly increased during and just after the explosive stage, and (2) that an increased proportion of the radiation pressure would be caught by the companion nebulæ, in cases in which both stars are disrupted, and that the nebulæ would be driven apart in a higher degree than in the case of undisrupted stars. Furthermore, stellar matter, in passing from the gaseous state in which it was ejected into condensed aggregates following its enormous expansion and its greatly enhanced radiation loss, would pass through those dimensional stages in which radiation pressure is most effective. In so far, therefore, as enhanced radiation pressure might offset gravitation after the stars had passed periastron and become dispersed thereby into nebulæ, there would be an increment of velocity to be added to the velocity previously acquired.

5. In the cases in which nebulæ are supposed to be produced by collision, there is likely to be a conversion of energy of translation into some form of dissociative energy with resulting loss of translatory velocity. If this is effective, there should be a class of nebulæ with low velocities, and these should be associated with dynamic indices of collision. This seems in a measure to be realized in the low velocities of certain nebulæ that bear forms which seem to imply a collisional origin, such as the Great Nebula of Orion, the Fish Mouth Nebula, and the Trifid Nebula. These form a class well differentiated from the flat, symmetrical spirals, as also from the typical planetary nebulæ whose forms imply a less dispersive mode of genesis.

Other Lines of Work.

The work of the year on problems of primitive earth-shaping has followed in the main the lines previously reported. The work on climatic states has been given chiefly to a more critical study of climatic evidences recorded in the Paleozoic and Mesozoic formations of South and Central Africa and the islands of the Indian Ocean.

Vaughan, T. Wayland, U. S. Geological Survey, Washington, D. C. *Study of the stratigraphic geology and of the fossil corals and associated organisms in several of the smaller West Indian Islands.* (For previous reports see Year Books Nos. 14 and 15.)

It had been hoped to submit for publication by the Institution the manuscripts for a volume which would comprise monographic accounts of the fossil organisms I obtained in Antigua, St. Bartholomew, St. Martin, and Anguilla, and of the available collections from Cuba; but the work has been interrupted by official assignments to other duties. However, there has been considerable progress in the study of the material. Dr. Joseph A. Cushman has completed a monograph of the fossil foraminifera from the Leeward Islands and one on the fossil foraminifera obtained in Santo Domingo by Miss C. J. Maury. In connection with the preparation of a monograph on the fossil corals of Central America, Cuba, and Porto Rico, I have worked over all the material obtained in the Leeward Islands and have prepared preliminary lists of the species for incorporation in the monograph mentioned. As a part of the memoir on the fossil corals from Central America, etc., I have written a rather elaborate statement of the geologic history of the Tertiary coral faunas of Central America, the West Indies, and the southern United States; and following it is an account of the conditions under which both the fossil and Recent coral reefs of the area under consideration have formed. This memoir will be published in Bulletin 103, U. S. National Museum, as one of a set on the paleontology of the Canal Zone and adjacent areas in Central America. Dr. R. T. Jackson has made progress with his investigation of the fossil echinoids of the West Indies. Mr. O. E. Meinzer, of the U. S. Geological Survey, has placed in my hands a paper describing the geology and the fossil coral-reefs in the vicinity of Guantánamo, Cuba, and Mr. N. H. Darton, also of the Survey, has delivered to me a manuscript describing the geology of an area near Guantánamo, Cuba, but a little to the northeast of the one considered by Mr. Meinzer. I intend to combine these two papers with my manuscript on the physiography and the stratigraphy of the island. Dr. Paul Bartsch has almost finished a paper on the living land mollusca of the Leeward Islands. These organisms furnish significant information on former land connections between the islands. Unless prevented by other duties, I hope within a few months to deliver to the Institution those manuscripts now near completion.

HISTORY.

Andrews, Charles M., Yale University, New Haven, Connecticut. *Preparation of a general history of the colonies in America.* (For previous reports see Year Books Nos. 14 and 15.)

During the winter of 1916–17, in such leisure as could be obtained from university and other obligations, progress was made in organizing the material obtained during the preceding year and a half, and opportunity was found to write one paper, based upon this material, entitled The Boston Merchants and the Non-Importation Movement, read before the Colonial Society of Massachusetts and published in its Publications for the year 1917. In May 1917, Raleigh and Edenton, North Carolina, were visited for the purpose of examining further the manuscripts there.

Osgood, Herbert L., Columbia University, New York. *Completion of an institutional history of the American colonies during the period of the French wars.* (For previous reports see Year Books Nos. 11–15.)

Both Dr. Russell and myself have been occupied continuously with the "History of the American Colonies in the Eighteenth Century." With the completion of three more chapters the greater part of the work will be done. The subject-matter for one chapter is almost wholly in England and has not yet been collected. The material for the others has not been to any extent organized and its preparation will require much labor. After these chapters are finished the revision and final shaping up of the work as a whole will follow. About two years longer will therefore be required before all the volumes are ready for the press.

LITERATURE.

Bergen, Henry, Brooklyn, New York. *Research Associate in Early English Literature.* (For previous reports see Year Books Nos. 11–15.)

Dr. Bergen reports that he has carried the Troy Book Glossary down to the latest part issued of the Oxford Dictionary, has completed the explanatory notes to the Troy Book, and made his final corrections for the press of the text of the Fall of Princes.

Tatlock, John S. P., Stanford University, California. *Completion of preparation for publication of a Concordance to Chaucer.*

Work on the Chaucer Concordance or Dictionary was actively resumed in February, under the supervision of Professor John S. P. Tatlock, of Leland Stanford Junior University, with the assistance of Dr. Arthur G. Kennedy, of the same university, and of Mr. Albert A. Bennett, A. M., Research Collaborator of the Institution. The work has consisted mainly of sorting the slips, numbering about 300,000; removing material certainly or possibly not to be printed, arranging the slips under their key-words, and alphabetizing them.

MATHEMATICS.

Morley, Frank., Johns Hopkins University, Baltimore, Maryland. *Application of Cremona groups to the solution of algebraic equations.* (For previous reports see Year Books Nos. 9–15.)

In the series of three articles on "Point Sets and Cremona Groups"[1] certain facts were developed which raised a presumption that the self-associated set of $2p+2$ points in Sp could be connected with the general theta functions in p variables, or, more specifically, that the absolute invariants of the set of points could be expressed in terms of theta modular functions. If this presumption is correct, then the point set would furnish a geometric background for the general theta function, just as the algebraic curve of genus p has served for the particular Abelian theta function. Thus far the only known cases in point are the hyperelliptic theta functions determined by $2p+2$ points on the rational norm curve in Sp (a particular case of the self-associated set), and the general theta functions for $p=3$, which are likewise Abelian. The possibility was strengthened further by the discovery[2] of configurations of theta characteristics which were grouped in the same way as the absolute invariants of the point set.

The investigations of the past year have disclosed that the point set defines by purely projective processes a finite group G which is isomorphic with the modular group H of the odd and even thetas. The extended group, defined in Point Sets II, which is attached to the point set and which for values beyond $p=3$ is infinite and discontinuous, contains an infinite invariant subgroup whose factor group is G. The identification of this group with H establishes the presumption mentioned above, though the precise algebraic nature of the connection remains to be investigated.

The importance of the basis notation, as set forth in an earlier paper,[2] for the odd and even thetas is emphasized by the manner in which the group G arises on the projective side, and this notation has been developed further.

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[1]Parts I, II, III, Trans. Amer. Math. Soc., vols. 16, 17, 18 (1915–17).

[2]An Isomorphism between Theta Characteristics and the $(2p+2)$-Point; Annals of Mathematics, Ser. II, vol. 17 (1916).

METEOROLOGY.

Bjerknes, V., Bergen, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–15.)

The investigations in dynamics and thermodynamics of the atmosphere have been continued.

The aerological observations obtained from the region of the North Atlantic trade-winds by the expeditions of A. Lawrence Rotch, Teisserenc de Bort, and Hergesell have been worked out by Mr. Sverdrup in his paper "Der nordatlantische Passat." The investigation gives a tolerably complete idea of the dynamics and thermodynamics of the trade-winds of this region. This result is very encouraging, as it may be concluded that it will be relatively easy to perform a complete investigation of the meteorology of the tropics. A ship cruising for a year or two in the Atlantic, the Indian, and the Pacific Oceans, making aerological observations, should be able to bring sufficient data for working out the dynamics and thermodynamics of the atmosphere in all the principal trade-wind and monsoon regions. This would be a good advance toward a complete theory of the great atmospheric circulations.

Returning to the more complex meteorological phenomena of our latitudes, the question of a rational dynamic prognosis has been made the subject of investigations.[1] The problem in its most elementary form has been this: wind and pressure being given at 8 a. m., calculate by use of the hydrodynamic equations the wind at 11 a. m., and so on. For this investigation observations obtained from the U. S. Weather Bureau have been used. Our efforts have had no direct success. The differences between the calculated and the observed winds were always great and irregular. This failure was not unexpected; careful examination indicated that its causes were:

1. Meteorological observations as we get them at present give, on account of the many local influences, very incorrect representations of the true atmospheric states.

2. Atmospheric friction in the neighborhood of the ground is an exceedingly complex function both of the topographical configurations and of the momentary atmospheric conditions.

This statement allows us to draw with great probability an important conclusion: the precalculations should have good prospect to succeed if based upon observations taken, not at the ground, but at a height of, say, 1,000 meters above the ground, *i. e.*, at a height where both functional resistance and local influences from the ground have prac-

[1]Cf. Sverdrup and Haltsmark's paper: Ueber die Reibung an der Erdoberfläche und die direkte Vorausberechnung des Windes mit Hilfe der hydrodynamischen Bewegungsgleichungen.

tically disappeared. All technical difficulties in obtaining such observations have been overcome by modern aerology. Thus, if in a country of the extent of the United States 50 meteorological stations were equipped for the ascents of kites and for the observation of air-motion by use of pilot balloons, it should probably be possible, not only to precalculate wind for short intervals of time with satisfactory accuracy, but also to produce general weather forecasts of practical value.

The attempt at precalculating the wind directly, while failing in its direct purpose, has led indirectly to another result which may be of practical importance. Isallobaric charts have been used hitherto only for extrapolating future charts of pressure. Taking the dynamic point of view, the rational use of the isallobaric charts will be, however, to extrapolate the future chart of wind, and the method of performing this extrapolation is very simple.[1]

The problems of weather forecasting based upon rational dynamic principles have been taken up also along other lines. Instead of applying directly the dynamic equations to a number of selected points, we may try to bring into application general theorems deduced from these equations. Thus a kinematic analysis of the charts of wind has shown that in the immediate environs of the lines of convergence and of divergence there exists a very characteristic distribution of vortices. This makes it possible to bring the theorems of the formation of vortices into application for finding the laws of the propagation of these lines. The result is the following simple rule:

> For one looking along the line in the direction of the wind a line of convergence will move to the right and a line of divergence to the left in the northern hemisphere.

This theoretical conclusion has been confirmed very satisfactorily by an examination of charts of wind from Europe. As these lines have very characteristic meteorological properties (thus every cold wave and every line-squall is preceded by a strong line of convergence), this rule may be of importance for weather forecasting.

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[1] Ueber die Beziehüng zwischen Beschleünigungen und Gradientenänderungen und ihre prognostische Verwendung.

NUTRITION.

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3–15.)

In our report for 1916 we stated that our results with commercial by-products, which are extensively used to increase the protein in rations fed to domestic animals, fully justified a continuance of these investigations and their extension to other largely used commercial products. Accordingly we have made a more detailed study of the effect of diets containing each of a larger number of such products as well as of combinations of these in various proportions. These investigations have shown wide differences in nutritive value between many of the substances tested, especially in respect to the rate of growth induced by equal quantities of them. Thus, young albino rats on a diet containing 9 per cent of protein in the form of cotton-seed flour in a given time gained as much in weight as those on a diet containing 18 per cent protein in the form of brewers' grains, the total food intake being the same, whereas when 9 per cent of protein in these latter grains was fed no growth at all was made.

Combinations of two such feeds were frequently more efficient than even larger proportions of either one alone. Thus, on a diet containing 6 per cent of soy-bean protein and 10 per cent of corn-gluten protein a gain of 51 grams was made in 3 weeks, whereas on a diet containing 15 per cent of corn-gluten protein alone 12 weeks were required to make the same amount of growth. Various proportions of many protein concentrates in numerous combinations were thus tested, with results which may guide those engaged in developing more economical methods of feeding domestic animals than are now in use.

The experiments with cotton-seed products mentioned in our last report have been extended and the results there described have been confirmed. It has been shown that *the decorticated seeds* contain something which is either toxic or so unpalatable that rats refuse to eat enough of the foods containing even small quantities of meal made from them to support life. This "toxic" substance is not present in the oil, for cold-pressed cotton-seed oil added to the diet in liberal amounts fails to affect the animals unfavorably. The ether extract from the cold-pressed seed residues contains the deleterious substance, for even a little of the solid from such extracts seriously impairs the value of the food. The ether-extracted meal promotes normal growth.

We found, with rats, that all the difficulties encountered in feeding cotton-seed meal, which have generally been attributed to a toxic substance in this seed, can be eliminated by heating the ground seed with steam. As this is usually done in the oil-mills before pressing out the oil, it is probable that the commercial meal can be rendered harm-

less by conducting the steaming process more thoroughly than is the present practice. Since rats have been brought to full maturity from a very early age and have produced vigorous broods of young when this seed furnished the sole source of protein, the high nutritive value of steamed cotton-seed meal is demonstrated. Furthermore, our experiments prove that cotton-seed meal is highly efficient as a supplement to protein-rich by-products from cereal grains.

Mention was made in our report for 1916 of soy beans as among the high-protein food substances with which feeding experiments were being made. In view of the rapid extension of the cultivation of this seed and its increasing use as food for man, as well as for domestic animals, our studies of it have been greatly extended and we have endeavored to learn as much as possible concerning its food value. We have found that (unlike most other leguminous seeds) soy beans fed as the sole source of protein, or as a supplement to corn gluten, promote the normal growth of young rats and maintain adults. They contain sufficient water-soluble vitamine; for diets containing soy-bean flour, butter-fat, starch, and an artificial salt mixture have promoted growth as well as comparable rations containing natural protein-free milk. The presence of some fat-soluble vitamine has been indicated by our long-continued growth experiments, which are still in progress. The mineral constituents of the soy bean are inadequate for growth, but the addition of suitable salts suffices to remedy this defect. Rats fail to eat sufficient food containing untreated soy-bean meal to make normal growth, but when the meal is heated with a little water they readily eat enough to fully satisfy all of their nutritive requirements. Meal heated without the addition of water is usually not eaten any better than the unheated. The raw, or dry-heated, meal is non-toxic; for the few animals which have eaten enough of foods containing such meals have grown well. Unlike cotton seed, raw soy beans extracted with ether are not eaten any more freely than the unextracted. A mixture of unheated soy-bean meal with corn gluten has proved satisfactory as the sole source of protein in the diets of chickens.

The high nutritive value thus shown by the soy bean, as well as by the proteins isolated from it, is interesting in connection with the results which we have obtained with the common kidney bean, *Phaseolus vulgaris*. Some years ago we showed that phaseolin, the chief protein of this seed, when prepared by extracting kidney beans with sodium chloride and dialyzing the extract, failed to even maintain rats when fed as the source of protein in an otherwise suitable dietary. It was non-toxic, for when it was fed with an equal quantity of edestin the rats made satisfactory growth. We have now found that if the phaseolin is boiled with water for a few minutes and then dried, or dissolved in alkali and reprecipitated by neutralizing, it is capable at least of maintaining rats without growth. On the other hand, phase-

olin prepared by extraction with sodium hydroxide is capable of inducing some growth in rats. Boiling this preparation of phaseolin fails to increase its nutritive value. Determinations of the utilization of these different preparations showed that only about 55 per cent of the raw phaseolin, prepared by extraction with sodium chloride, is utilized, whereas about 82 per cent of it is utilized after it is boiled. The phaseolin prepared by extraction with sodium hydroxide is utilized to the extent of about 82 per cent when raw and 85 per cent when boiled. These experiments are now being verified and extended in the hope of gaining more precise knowledge as to the nutritive value of this important leguminous seed and the explanation of the unexpected phenomena noted. In this connection the recent observations of Falk (*Journal of Biological Chemistry*, 1917, vol. 31, 97) on the effect of heat and alkali on enzymes, proteins, and peptides in respect to their hydrolytic action on esters are suggestive that similar transformations in the phaseolin molecule may be involved here. Falk points out that the conditions which affect this hydrolytic action are the same as those affecting tautomeric changes in the R-CO-NH-R grouping of known organic compounds; and since the amino-acids are thus united in the protein molecule it is not improbable that tautomeric changes of the keto-lactam and enol-lactim type may occur under the influence of heat or alkali, two conditions which we have found to affect the utilization as well as nutritive value of phaseolin.

Our report for last year stated that the use of yeast as a source of food hormones would enable us greatly to extend the field of our investigations. During the past year we have devoted a large part of our time to studying the effect of small additions of this substance to diets containing the inorganic constituents in the form of mixtures of purified chemicals. We have directed especial attention to the quantitative requirements of rats for such essential dietary factors supplied by yeast, so that foods might be used which contained the least possible additions of substances of unknown nature.

We have found that there is a marked quantitative need for such substances, but that individual animals differ to some extent in this respect. Although the great majority of our rats grew normally when 1.5 per cent of dried yeast was added to the diet, some required as much as 2 per cent, while others throve on as little as 1 per cent. A very few needed only 0.5 per cent to make a corresponding growth.

Having learned the proper quantity of yeast to use, we have undertaken an elaborate series of experiments on the role of the individual inorganic ions in the nutritive processes. To rations consisting of highly purified proteins, starch, lactose, and fats, we have added mixtures of inorganic elements in which the qualitative and quantitative relationship of the various ions was altered at will. The only inorganic impurities which impaired the precision of these tests were

the traces present in the food substances and also in the small amount of yeast used to render the diets capable of maintaining our experimental animals. These traces have, however, been determined by chemical analyses, so that an exact knowledge of the inorganic intake has been obtained.

These studies will occupy much of our attention for some time to come. One of the interesting facts thus far established is that while calcium is needed in relatively large amounts, extremely small quantities of the other inorganic elements, with the exception of phosphorus, suffice for long-continued growth. Calcium can not be replaced by magnesium. Concerning the requirements for phosphorus, our experiments are not yet sufficiently advanced to justify definite statements, since the experimental conditions under which this element must be fed are more complicated than those involved in studying the other elements.

By determining the minimum for each element and the possible supplementary, or antagonistic, interrelations which they may manifest, it ought to be possible to supplement the inorganic deficiencies of certain naturally occurring foods more intelligently than can be done at present. It is possible that some day more rational principles can be applied to the selection of inorganic supplements to the diet, in accord with the law of minimum which applies so widely in biological phenomena, and that new methods may be developed for controlling some of the pathological conditions with which physicians have to real. A wide, new field is thus opened for future investigation of many factors essential for nutrition in growth and maintenance to which we expect to contribute much of interest during the coming year.

Stimulated by the desirability of obtaining other sources of water-soluble vitamine which might enable us to improve our methods for studying many problems of nutrition and metabolism which otherwise would be impossible, we are investigating many naturally occurring substances. In view of the marked superiority of our "protein-free milk," both as a source of water-soluble vitamine and suitable inorganic salts, we have tested by-products of the milk industry, hoping that these might afford a cheap and easily obtainable substitute for the product which we have heretofore made in our laboratory. The outcome has been disappointing, probably owing to the commercial methods used in handling the milk-sugar residue.

A number of our former experimental animals showed in their kidneys or bladder the presence of phosphatic calculi. Since none of our stock animals was ever thus affected, it was of interest to correlate this condition with the diet used. Of the 81 rats which developed calculi, out of 857 rats autopsied, 79 had been deprived of the fat-soluble vitamine for periods of from 35 to 325 days. One of the remaining two was without this substance for 21 days and the other for 11 days. The latter was a very young rat from a lot of physically

inferior animals purchased from a dealer before we had established our own breeding-colony. None of our rats which have been continuously supplied with a diet containing sufficient fat-soluble vitamine has ever developed calculi, so far as our autopsies have revealed.

Such calculi are usually assumed to arise from ammoniacal decomposition of the urine, caused by infection. All of our experimental animals which have not had an adequate supply of the fat-soluble vitamine have ultimately failed and many have shown a susceptibility to a form of infectious eye disease speedily cured by foods containing fat-soluble vitamine. An etiological relationship between the rations deficient in this vitamine and the formation of phosphatic calculi is indicated, since *in every case* of calculi the animal had existed for some time on such a diet.

In our report for 1916 we furnished data respecting the effect of stunting on the physiological life of rats after growth was resumed. Our completed records now show females which were stunted to the ages of 396, 538, 380, and 190 days respectively, giving birth to litters of young at 32 months (2 young), 28 months (3 young), 25 months (2 young), and 25 months (5 young). Since the sexual life of all these rats had extended well beyond the greatest age (22 months) at which the menopause has been reported to occur, it appears as if such a preliminary stunting period would lengthen the total span of life, unless this were shortened by disease or accident. Unfortunately direct evidence in support of this view was not furnished by any of these animals, for all died of lung disease, although at an age of over 2 years. This is a longer life than two-thirds of our stock rats have attained.

The experiments with chickens referred to in our last report have encouraged us to continue them, for if it should be possible to feed these birds successfully under strictly controlled conditions the essential factors for their nutrition could be established and many questions now in dispute settled. Furthermore, since birds excrete at least 20 per cent of their food nitrogen as ammonia, and the balance chiefly as uric acid, it is probable that their nitrogenous requirements may be in some respects different from those of mammals. The source of such excreted ammonia has not been established, nor its possible relation to the amide nitrogen which proteins yield as ammonia when boiled with acids.

We have accordingly undertaken a new series of experiments, using chickens taken directly from the incubator. The results thus far obtained indicate ultimate success, but have not yet reached a point where it is safe to draw final conclusions.

Last year we stated that it was expected that the results of anaphylaxis experiments (then being tried by Professor H. G. Wells with preparations of milk proteins which we had made) would soon enable us to give an account of our study of the proteins of milk. The outcome of these experiments showed that more work was necessary before our results could be put in final form. This work is now practically completed and will be published soon.

Having learned much concerning the relative value of many individual proteins obtained from various seeds, the next subject for investigation should be the nutritive value of the total proteins as they naturally occur together in the seed. A beginning has already been made along these lines, using certain seeds rich in oil, *e. g.*, the cotton seed; for after removing the oil the residues contain enough protein for use under the conditions of our methods of experimental feeding.

Heretofore seeds rich in starch, *e. g.*, the cereals, could not be studied in this way, although some information of value has been obtained by feeding protein concentrates produced commercially. We are now engaged in developing methods for removing starch with the least possible loss of protein and have every reason to expect results which will materially increase our knowledge of the food value of such seeds. We also believe we shall be able to secure from several important seeds preparations of some of their proteins which will be better than those heretofore obtained only in small quantities and in a state of doubtful purity.

In the past it has been the custom of those concerned with problems of nutrition to assume that all of the nitrogen present in seeds which can not be extracted by the solvents usually employed belongs to proteins. While this assumption may be correct, it is supported by such very unsatisfactory evidence that efforts should be made to determine as definitely as possible the nature of this insoluble nitrogen. The work which we now have under way, involving the removal of starch, ought to give us an opportunity to investigate this problem more thoroughly than heretofore, and attention is now being directed to this end.

The purpose of these experiments is to bring the results of our past work into closer relation to the problems presented by the practical feeding of domestic animals, for we believe that when we know as accurately as possible the actual nutritional requirements essential for normal growth and continued maintenance, and how these can be supplied by the use of such foodstuffs as are available, improvements and economies can be introduced into practice. Our investigations of the past years have shown us how to prepare the individual proteins contained in many of the more important food products, what the characteristics of their chemical constitution are, and how far each of these proteins meets the needs of growing or adult animals. We have learned that many of these proteins are inadequate as the sole source of protein and have shown that this is in most cases due to a deficiency in one or more amino-acids. We have shown that these deficiencies can be overcome by adding the lacking amino-acids themselves or by combining two proteins which supplement each other in respect to chemical structure. We have obtained some data concerning the relative nutritive value of a few seeds when fed as a whole, but still require further knowledge regarding many others, especially the cereal grains. It is our hope that investigations along the lines just indicated will supply much of the information which is still needed.

PALEOGRAPHY.

Loew, E. A., New York, N. Y. *Associate in Paleography.* (For previous reports see Year Books Nos. 9–15.)

With publications begun on the other side still suspended by the war, the fall and winter months were spent on an investigation of the Latin manuscripts in the collection of Mr. J. Pierpont Morgan. The oldest manuscripts in this collection are of such venerable antiquity that they would be considered rare treasures in any of the great European libraries and are of distinct interest to the student of paleography as instructive specimens of a number of well-defined types. The collection contains, besides the oldest manuscript of the letters of the Younger Pliny, mention of which was made in my last report, the only known dated uncial manuscript of the seventh century, the St. Augustine written in the year 669 in the celebrated abbey of Luxeuil; also manuscripts which exemplify the hand of the school of Tours, the Merovingian hand practiced at Luxeuil, that in use at the abbey of St. Gall, and fragments in the Beneventan and Anglo-Saxon hands.

The results of this investigation are to appear in the form of a detailed and amply illustrated catalogue, to be published, conditions permitting, by the Clarendon Press.

With regard to the Bobbio Missal, mentioned in my last report, it may be found necessary to publish it without the adequate introduction which was purposed, inasmuch as this involved another examination of the manuscripts.

The joint study by Professor Rand and Dr. Loew on the Morgan Pliny, referred to above, will be sent to press shortly. The months of April and May were spent in Ithaca, where a chapter on the dating of uncial manuscripts was added to this study.

During the year two other libraries have been visited and examined: the New York Public Library and the library of Henry Walters, esq., at Baltimore. The former is composed chiefly of liturgical manuscripts of the fifteenth and sixteenth centuries, while the collection of Mr. Walters contains manuscripts from the ninth century on.

PALEONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. *Study of the vertebrate fauna and paleogeography of North America in the Permian period, with especial reference to world relations.* (For previous reports see Year Books Nos. 2, 4, 8–15.)

Work under this grant has been largely directed during the last year to the collection and correlation of data bearing upon the stratigraphy, climatology, life, and paleogeography of the late Paleozoic, especially in North America. Much important material has been gathered, both by original investigation and by the compilation of the results of other workers, but the number of publications it is necessary to consult is so great and the area to be covered so large that much remains to be done, and it is only possible to report satisfactory progress. While material has been collected which would permit the publication of numerous short preliminary papers, the outlook upon the subject and the consequent method of treatment is developing so rapidly that it has seemed best to retain the material for publication in a single volume.

Urgent necessity in other lines of work made it impossible to undertake a field expedition in the summer of 1917.

Hay, Oliver P., U. S. National Museum, Washington, D. C. *Associate in Paleontology.* (For previous reports see Year Books Nos. 11–15.)

During the past year Dr. Hay has been engaged in further study of Pleistocene vertebrate materials, in trying to reach some general conclusions, and in preparing the manuscript of his report. Especial attention has been given to the geology and the paleontology of the Pleistocene of the States occupying the region of the Great Plains and around the Gulf of Mexico. In nearly all of these States there are found, in considerable abundance, fossil remains of mammals which belonged evidently to the early part of the Pleistocene. In Texas there is a low plain, about 90 miles wide next to Louisiana but considerably narrower as the Rio Grande is approached, which is occupied by the Pleistocene formations known as the Lissie and the Beaumont. The opinion has been expressed by geologists that the materials of these formations were brought down by the rivers and spread out on the sea-bottom at their mouths. Under such circumstances one might expect to find abundant fossil marine mollusks and some bones of marine vertebrates. On the contrary, at many places and at various depths, down to the coast, have been found remains of mastodons, elephants, and horses, some of these belonging evidently to the early part of the Pleistocene. During its formation the plain must have been sufficiently above water to permit the presence of a dry-land fauna. The writer believes that the greater part of this plain is older geologically than has been supposed.

The same early Pleistocene fauna is found to continue around the Gulf into Florida, with some interruption apparently in Louisiana.

Some time has been devoted to the study of the vertebrate fauna discovered at Vero, Florida, in association with human bones and artifacts.

As regards the final report, some hundreds of pages of manuscript have been prepared.

During the year Dr. Hay published a few papers pertaining to the subject he is studying. They are listed on page 40 of this volume.

Wieland, G. R., Yale University, New Haven, Connecticut. *Associate in Paleontology.* (For previous reports see Year Books Nos. 2–4, 6–9, 11–15.)

The first half of the year was devoted to South American field work. This began with a study of the Rhætic of the Andine front ranges southwest and westerly from Mendoza, Argentina. To the fossil plants there secured, supplementary collections were courteously added by the Argentine Geological Survey. A complete section through the Jurasso-Cretaceous of Neuquen, in latitude 40°, between the Patagonian plateau and the Andes, was examined for plant material. The main section was made in the valley of the Picun Leufu, between Cabo Alarcon on the Rio Limay and the Chalil Mountain, but various side-trips were included. It has long been known that a great development of fresh-water Mesozoic strata, from 5,000 to 10,000 feet in thickness, occurs in this region, although aside from the invertebrates of the lesser marine interpolations few fossils are recorded from the eastern flanks of the Andes. It seemed from the reported constitution of the beds that much petrified material could be found—if not cycadeoids, at least the stems of the contemporaneous conifers. This proved to be the fact. Especially in the Jurassic sediments of Neuquen, the well-conserved stems of conifers are abundant in many horizons. The possibilities of collection are great, and if cycadeoids of the large-stemmed types existed in the southern hemisphere they must occasionally have been conserved and will sooner or later be found. A good coniferous-stem collection was secured and is now being sectioned. Taken with the few forms described in recent years from Antarctica, it must include sufficient variety of species to greatly extend our knowledge of culminant coniferous forest distribution in mid-Mesozoic time. The study of this new material supplements thus the cycadeoid-stem investigation announced as already under way last year.

Partly due to a certain lack of strata with well-conserved plants, and partly because of fortune afield, no opportunity was had to extend previous work on Liassic imprints; but incidentally nearly the entire eastern limit of the Argentine *Araucaria imbricata* forest was examined with care—particularly all round the Chalil, westerly toward Lago Aluminé and along the valley of the Cataluin to the southern boundary, with later observation of the Chilean development. Reference to this pure-stand climax forest of ancient type has already been made in volume II of American Fossil Cycads. It is of economic significance

that the Argentine lakes within the limits of this forest find their exact geologic and climatic counterparts in the State of Washington next the dry interior basin. Lake Chelan is one of these physiographic equivalents of such lakes as Aluminé and Huechulafquen, about which the forests are so remarkable. The araucarias can again be brought back to the northern hemisphere.

This year the seeds failed in both the Argentine and Chilean forests. It appears to be a singular fact that throughout the entire araucarian region on both sides of the Andes the seeds are abundant only in alternate years; every other year they may be had cheaply for purposes of seeding, when locally gathered as a much-prized article of food. It is also of interest that the young seedlings from the forests of the upper Bio Bio Valley of Chile endured the roughest treatment during six weeks' journey home and are now growing. This tenacity of life is more like that shown by cycads than by any conifers.

Field observation of the araucarias, which also included a brief glimpse of the Brazilian forest of Santa Catarina, shows that they have a much broader resemblance to the cycadeoids than has been hitherto appreciated. Without going into a technical description, it may be stated that the branching habit of the heavy-stemmed cycadeoids and *Araucaria imbricata* is nearly the same. The latter at times has stems of remarkably robust form. It may reach 5 feet in diameter with a height of no more than 50 feet, and little tapering, while forms 3 feet thick by 30 high are not unusual. As compared with other conifers, the lateral branches are much suppressed and new shoots are freely sent up from the huge roots. The frequent occurrence of stem bifurcation and the occasional examples of from 3 to 5 heavy stems growing in a clump at once recall the cycadeoids; so does the development of the woody cylinder of both the fertile and vegetative branches, the medulla being large. It is intended to give this parallelism between *Araucaria* and the cycadeoids further consideration. It includes anatomical features of deep interest in any adequate theory of gymnosperm origin and descent.

After the field work in Neuquen the Andes were traversed by way of the lake region, southern Chile being reached as the rainy season set in. Fortunately, however, during one week of examination of the araucaria forests of the upper Bio Bio Valley, the weather was exceptionally fine; also, during rainy weather a preliminary examination was made of the considerable thicknesses of early Mesozoic deposits containing plants in the lower Bio Bio Valley. These find extended development along the western flanks of the Nahuel Bute range, and from the facts observed and learned it is believed are in part Liassic. They were found to contain many fossil plants and are a fresh-water series of wide interest.

PHILOLOGY.

Churchill, William, Washington, D. C. *Associate in Primitive Philology.* (For previous reports see Year Books Nos. 14 and 15.)

The principal investigations during the year have been devoted to an ethnological examination of the problems of Polynesian migration through Melanesia, which in former researches have been dealt with along lines purely philological. In the pursuit of this branch of the subject I made a careful collation of the several thousand pieces of South Sea ethnica contained in the museum of the University of Pennsylvania. In connection therewith grateful acknowledgment is made of the facilities cordially offered by the Provost of that university and by Dr. George Byron Gordon, the director of the museum. Particular interest centered upon the collection of war weapons, their form, fencing art, metrology, decoration. This material has been digested in the monograph "Club Types of Nuclear Polynesia" (Publication No. 255), in which intimate attention has been directed upon the evolution of wooden club forms from precedent weapons in which stone and shell heads were mounted upon wooden hafts. In this study it has been possible to trace the movement of races eastward into Nuclear Polynesia from discrete culture horizons in distant Melanesia and thus to confirm by material objects several of the conclusions already reached in the linguistic discussion of the problem.

I have had the opportunity to revise the manuscript of the Sa'a-Ulawa dictionary compiled by the Rev. Walter G. Ivens and to give such assistance as in my power to forwarding this work through the press.

PHYSIOLOGY.

Reichert, E. T., University of Pennsylvania, Philadelphia, Pennsylvania. *The differentiation of starches of parent-stock and hybrids.* (For previous reports see Year Books Nos. 9–15.)

Dr. Reichert states that he is closely approaching the completion of his memoir. His calculations of the time required to complete the investigation have been upset mainly on account of the novel character of the research, but the results are satisfactory and the report will find a place among the unique and fundamental contributions of biological literature. The results are not only in accord with the fundamental findings of the two previous researches, but extend many steps farther and lead the way to collateral work of the greatest importance.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. *Continuation of investigations in interferometry.* (For previous reports see Year Books Nos. 4, 5, 7–15.)

In a volume submitted to the Institution, Professor Barus pursues the work on the interferences of reversed and non-reversed spectra, begun in his last report (Carnegie Publication No. 249, 1916), in a variety of promising directions, such as the original investigation suggested. It will be remembered that the reversal (180°) here contemplated takes place on a transverse line of the spectrum (*i. e.*, a line parallel to the Fraunhofer lines), which thereby becomes a line of symmetry for the phenomena. Apparatus has been extensively modified so as to admit of measurements relating to individual fringes.

A large portion of the first section is devoted to the treatment of prismatic methods, developed with the additional purpose of securing intensity of light. A curious intermediate case between interferences of reversed and non-reversed spectra is the pronounced interference of spectra from the same source but of different lengths (dispersion) between red and violet. The phenomena of crossed rays find a parallel occurrence in the present paper when similar gratings or prisms disperse and subsequently recombine a beam of white light. A type of fringes is detected which depend merely on the grating space and is independent of wave-length. An interesting question as to the limits of micrometer displacement within which fringes of any kind are discernible (observations which were at first supposed to be due to the degree of uniformity of interfering wave-trains) is eventually shown to be a necessary result of dispersion. Finally, the direct interference of divergent rays obtained from polarizing media is exhibited.

In the second section the interferences of inverted spectra (a subject merely touched in the preceding volume) are given greater prominence. In this case one of the two spectra from the same source is inverted (180°) relatively to the other on a longitudinal axis (*i. e.*, an axis normal to the Fraunhofer lines), which thus becomes a line of symmetry. In the development of the subject, spectra half-reversed and spectra both reversed and inverted are treated successfully. In the latter case the conditions of interference are fulfilled at but a single point in the whole area of the field, yet the phenomenon is pronounced. The limits of micrometer displacement within which interferences may be obtained are again determined.

The third and fourth sections are incidental applications of the displacement interferometer and contain experiments on the expansion of metal tubes by internal pressure and on a promising method of measuring the refraction of glass irrespective of form.

The fifth section begins the development of displacement interferometry in connection with the older Jamin-Mach interferometer, an instrument which has certain peculiar advantages and is in a measure complementary to the Michelson interferometer. The work was undertaken in connection with the micromeasurement of the difference of heights of communicating columns of liquids.

The chief result of the paper is the detection of the achromatic interferences (so called for convenience), interferences which are ultimately colors of thin plates seen at oblique incidence. But with the new interferometer and obtained with white light, they are peculiarly straight and vivid and resemble a narrow group of sharp Fresnellian fringes with the central member nearly in black and white. They are capable of indefinite magnification and their displacement equivalent is a fraction of a mean wave-length per fringe. Notwithstanding their strength and clearness, they are so mobile in connection with micrometric displacement that in general it would be almost hopeless to find them but for the fact that they coincide in adjustment with the centered ellipses or hyperbolæ of the spectrum fringes of the displacement interferometer. The fine, white slit-image which is dispersed to produce the latter carries the achromatic fringes when the slit is indefinitely broadened or removed. The paper shows a curious method for the measurement of vertical displacements, possibly available for the detection of ether drag, which though just insufficient in connection with the spectrum fringes would be promising in connection with the achromatic fringes. Finally, the paper contains some work similar to the old experiments of Fizeau on the periodic evanescence of fringes due to the sodium lines.

The peculiar adaptability of the new interferometer to the measurement of small angles, either in a horizontal or a vertical plane, is developed in the final section. The ratio of the displacement of fringes and the angular displacement to be measured may be made enormously large, and the paper shows cases in which, with strong luminous fringes, the angle to be measured is magnified 500 times. Moreover, this is by no means a limiting performance. Again, while angles as small as a few tenths second or less are measured, angles as large as several degrees come naturally within the scope of the method. Similar remarks may be made with respect to the ratio of angular displacement and micrometer displacement. Given, therefore, an apparatus which measures very small angles without constraint or forced approximations, the measurement of long distances is the next result in order; for it is merely necessary to place the angle to be measured at the apex of the distance triangle on the length b of the ray parallelogram as a base. This may be done in a variety of ways, some of which are shown in part 2 of publication 249.

The fringes here in question are preferably the very luminous achromatic fringes. They have been identified as ultimately colors of thin plates, but they look like Fresnel's fringes. In connection with this work, however, another type of fringes was detected, obtainable with a fine slit, white light, and in case of centered spectrum fringes when the ocular of the telescope (or the eye) is out of focus. These are actually Fresnellian interferences, but being made up of broad concentric hyperbolic areas, brilliantly complementary in color, they resemble the lemniscates of biaxial crystals without the shadows.

Hayford, John F., Northwestern University, Evanston, Illinois. *Investigation of the laws of evaporation and stream-flow.* (For previous reports see Year Books Nos. 12–15.)

Professor Hayford's report covers the period from August 1, 1916, to July 31, 1917. But little progress was made during the year, due to the indirect influence of war conditions, and the expenditures were correspondingly small. The progress stopped entirely in June 1917, since which time he has been engaged in certain scientific work connected with the Government in addition to his regular college duties. The progress made was principally a direct continuation of that indicated in the annual report for the period August 1, 1915, to July 31, 1916. Nothing especially new was developed, though real advance was made in securing increased accuracy and in confirming earlier conclusions.

The computers during the year were, F. D. Danielson, J. A. Folse, T. Doll, R. M. Quirk, M. F. Hayford, F. Mohr, A. McMurdie, H. G. Bersie, and C. W. Froehlich. Over 90 per cent of the computing was done by four of these men, Messrs. Danielson, Folse, Doll, and Quirk.

Howe, Henry M., Columbia University, New York, New York. *Research associate in metallurgy.* (For previous reports see Year Books Nos. 6–15.)

During the year 1916–1917 I have explained the abruptness of the transition from the columnar to the equiaxed structure in slowly solidified masses of metals and other substances, including rocks, as representing the moment when the thermal gradient in the region in which solidification is occurring becomes so flat that the less fusible molten matter at a material distance from the face of the already solidified walls now solidifies before the more fusible layer of molten in immediate contact with those walls, made more fusible by the selection in solidification. Up to this moment solidification has occurred at the tips of the columnar crystals forming the now solid walls, and hence has been columnar. From this moment it occurs about nuclei disconnected with those columns.

I have investigated the laws and explanations of "grain growth," *i. e.*, the increase in size of the individual allotriomorphic crystals of

which metallic masses are composed, with corresponding decrease in the number of crystals. The results are not yet ready for summarizing.

I have studied the erosion of great guns at the request of the Naval Consulting Board. The work thus far has consisted chiefly in an analysis of the conditions causing erosion, as disclosed by microscopic examination of eroded gun-tubes. I infer that materials which resist erosion should combine with a high melting-point the property of "white-hardness" and great thermal conductivity, density, and specific heat. I have found that the collective width of the cracks formed in eroded gun tubes is far more than can be explained by simple expansion and contraction, and I refer this excess to cumulative cracking, caused by the stopping of the mouth of each crack with a mouthful of copper which its hardened steel lips bite off from the copper driving-band of the projectile as it passes.

An exhaustive series of experiments into the causes of the effects of heat treatment on the properties of steel has been projected and begun. In carrying out this work I shall have the collaboration of Sir Robert A. Hadfield, of Sheffield, England, whose experimental laboratory is well equipped for making the needed mechanical tests. The United States Bureau of Standards also has indicated a willingness to collaborate in this work.

The output of work for the current year has been interfered with very greatly by the labor of installing a new metallographic laboratory at Bedford Hills, New York, and the transfer to it of the work formerly done at Columbia University. The freedom of the new laboratory from interruption, and its being exclusively for my own scientific investigations, should increase the output of work hereafter.

Nichols, E. L., Cornell University, Ithaca, New York. *Systematic study of the properties of matter through a wide range of temperatures.* (For previous reports see Year Books Nos. 4–15.)

New Absorption Bands.

Complete maps of the fluorescence and absorption of the double chlorides have been made during the year and the wave-lengths, frequencies, and intervals for all observed bands have been tabulated and discussed. This work is supplementary to the detailed study of the polarized spectra of the four chlorides mentioned in this report for 1916 (Year Book No. 15, p. 382).

In the course of the investigation the range of the absorption spectrum was greatly extended towards the red. The newly discovered bands are discernible only when light is transmitted through very thick layers and when special precautions are taken to prevent fluorescence. They correspond in position with the fluorescence bands of that region and have therefore the frequency interval of the fluorescence series instead of the shorter interval of the absorption system. By means of these observations, which were made by Dr. Howes, we

now have an absorption band corresponding to each fluorescence band throughout groups 8, 7, 6, and 5 of these spectra, and there is reason to think that with crystal layers of sufficient thickness absorption would be found to accompany fluorescence throughout the entire spectrum.

The determination of the limits of the absorption spectrum in direction of decreasing wave-length, on the other hand, demands the use of very thin layers. With crystals having a thickness of the order of 1 mm., all the uranyl compounds become opaque at about 0.4μ, but recent photographs using much thinner layers reveal the presence of bands extending well into the ultra-violet. A detailed exploration of this region is contemplated.

Structure of Uranyl Spectra at +20°.

The study of the fluorescence spectra of the uranyl compounds, with the exception of the spectra of the double chlorides, where the bands are distinctly resolved into groups, has consisted for the most part in the location of the rather broad bands. Many of these spectra, however, show indications of complexity. Dr. Frances G. Wick has made a complete tabulation of the fluorescence bands of numerous spectra not previously mapped. She has also determined the envelope by the method (described in our earlier investigations)[1] of measuring the relative brightness of the bands with the spectrophotometer. The wave-length of the crest of the envelope is found to be the same for all the members of a given family of salts, such as the double nitrates, the double sulphates, or the double acetates, but varying from family to family. Detailed spectrophotometric studies of individual bands show that although in general these appear to the eye as simple, they consist of a complex of closely overlapping components even at +20°, which on cooling resolve into the well-known groups which constitute the spectrum of low temperatures.

The Double Nitrates.

The study of the fluorescence and absorption of the double nitrates mentioned in the Year Book for 1916, p. 382, has been extended to four forms: $NH_4UO_2(NO_3)$, $(NH_4)_2UO_2(NO_3)_4.2H_2O$; $KUO_2(NO_3)_3$, and $K_2UO_2(NO_3)_4$. Three crystal systems are represented. The investigators, Dr. Howes and Dr. Wilber, have reached the following conclusions.[2]

1. The spectra of the double uranyl nitrates resemble those of the previously studied uranyl salts in that the bands can be arranged in series having constant frequency intervals.

2. These intervals, while constant for any given series, are different for different series.

3. In the mono-ammonium uranyl nitrate and the mono-potassium uranyl nitrate the ratio of the interval of a fluorescence series to the

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[1] Nichols and Merritt: Physical Review (1), XXXIII, p. 358, 1911.
[2] Howes and Wilber: Physical Review (2), X, p. 348 (1917).

interval of the absorption series which joins that fluorescence series is approximately a constant.

4. Although the grouping of the bands shows a strong family resemblance in the four spectra, the absolute position of a group is largely determined by the crystal system.

The Acetates.

A determination (similar to those completed in the case of the chlorides and nitrates) is being made upon the spectra of the uranyl acetates. The members of this large family of double and triple salts are nearly all fluorescent and many of the spectra are finely resolved at the temperature of liquid air. Photographs of the numerous preparations made for this work by Dr. Wilber have been made and measured and the results mapped. The final comparison and discussion of the data is well advanced.

Phosphorescence of Long Duration.

In the course of a recent comparison of the spectra of certain uranyl salts when excited to fluorescence by the kathode discharge with the same spectra under photo-excitation, Doctors Louise S. McDowell and Frances G. Wick discovered that brilliant phosphorescence visible in some instances for several minutes was developed by the action of the kathode rays. It appears from their preliminary survey of this new field that:

1. The phenomenon occurs only at low temperatures.
2. The effect is gradually built up under the action of the discharge, exposure for several seconds being necessary in most cases.
3. The substances thus affected show no phosphorescence of appreciable duration under the action of light, whether excited before or after exposure to the kathodic bombardment.
4. The type of decay is that characteristic of persistent phosphorescence in general, there being two processes. The first and more rapid lasts 15 or 20 seconds, under the strength of excitation employed. The second is much slower and continues to the end or at least as long as the glow is of measurable intensity. Both processes follow the usual law, *i. e.*, the square root of the intensity is inversely as the time from the close of excitation.

This type of phosphorescence differs strikingly from the phosphorescence of the uranyl salts under photo-excitation, recently described,[1] in which the first process of decay is slower than the subsequent decay and in which the total duration is a few thousandths of a second. The relations of the two are under investigation.

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[1]Nichols: Proceedings of National Academy of Sciences, II, p. 328, 1916; also Nichols and Howes: Physical Review (2), X, p. 293 (1917).

A New Form of Uranyl Nitrate.

Dr. F. E. E. Germann, in a study based upon work of Dr. Howes[1] on the fluorescence of frozen solutions, has isolated a new hydrate of uranyl nitrate having 24 molecules of water of crystallization. The crystalline form of this substance, which melts at $-35°$ C.$\pm$, and the relations of its spectrum to the hydrates with 1, 2, 3, and 6 molecules,[2] are under examination. Dr. Germann's method, which involves the determination of the curves of cooling of solutions of various degrees of concentration, will be extended to other uranyl compounds.

The Structure of Broad Fluorescence Bands.

The fluorescence spectrum of the uranyl salts, as has been repeatedly demonstrated in the course of our investigations, is a complex of equidistant components. This structure has been shown to be common to all the compounds thus far studied and has been considered as perhaps peculiar to them. Whether a similar structure exists in the case of other fluorescence spectra is difficult to determine, especially because in the usual broad-banded type the merging of the components is almost complete and no method of resolution has as yet been discovered. Evidence of complexity, however, has been found from time to time. A study of existing data on the fluorescence of commercial anthracene, using the measurements made by Miss McDowell, who photographed the visible and ultra-violet bands, shows that this spectrum is made up of two partially overlapping complexes, one due to the fluorescence of chrysogen, having a constant frequency interval of about 131, and the other due to anthracene with an interval of about 121.

Dr. Howes, who has recently completed a discussion of McLennan's data on the ultra-violet fluorescence of iodine vapor,[3] finds that all the bands of this complicated spectrum may be arranged, like the bands of the uranyl spectra, in series having constant frequency intervals; also that there is a strikingly symmetrical grouping of the bands around certain mercury lines which were employed as sources of excitation.

An analysis of very careful and detailed spectrophotometric measurements of the broad bands of the phosphorescence sulphides has revealed a similar structure in these spectra.[4] They are found to consist of components forming one or more series of constant frequency, as in the uranyl spectra, but so closely overlapping as to give the appearance of a single homogeneous band. It is proposed to extend such observations to other fluorescent materials in order to determine whether this is the general underlying character of luminescent radiation.

[1]Howes: Physical Review (2), VI, p. 192 (1915).
[2]Nichols and Merritt: Physical Review (2), X, p. 113 (1917).
[3]J. C. McLennan: Proceedings Royal Society, LXXXVIII, p. 281, and XCI, p. 23.
[4]Nichols: Proceedings of Amer. Phil. Society, LVI, p. 258 (1917).

Selective Radiation of Rare Oxides.

Mr. W. G. Mallory has nearly completed his study of the selective radiation of certain rare oxides. It is established, by direct spectrophotometric comparison of the radiation from erbium oxide with the radiation of a black body having the same temperature, that the intensity in the bands greatly exceeds that of corresponding wave-length from the black body, whereas the intermediate regions are relatively much weaker.

Electrical and Thermal Properties of Iron Oxides.

Dr. Bidwell's measurements of the resistance and thermo-electric power of these oxides have been carried to the melting-points at about 1,520° and values of the thermal conductivity of Fe_2O_3 to 1,050° have been obtained. The previously reported[1] transformation of Fe_2O_3 at 710° to 730° is verified. Below this point the thermo-electric line is straight, but a maximum positive value is reached in the neighborhood of 1,125° C., above which temperature the values decrease to zero and become negative. A transformation at 1,320°, probably involving some further change of structure, is clearly indicated by the trend of the thermo-electric line.

The electrical resistance of Fe_2O_3 is found to obey the exponential law suggested by Königsberger for substances of this class. The change of thermal conductivity of Fe_2O_3 is found to be a linear function of the temperature. The widely different electrical behavior of Fe_3O_4 as compared with Fe_2O_3 is clearly brought out in the data.

Miscellaneous.

The work of Mr. C. C. Murdock on photo-electric currents in cells having a fluorescent solution as an electrolyte is nearly completed.

The researches of Dr. R. W. King on thermal conductivities and on the properties of thin films,[2] and those of Mr. Austin Bailey on the Zeeman effect in the reversible bands of the uranyl spectra, have been interrupted by the war, which has called these and many other members of our staff to other duties.

PSYCHOLOGY.

Franz, Shepherd I., Government Hospital for the Insane, Washington, D. C. *Investigation of the functions of the cerebrum.* (For previous reports see Year Books Nos. 4–10, 12, 15.)

Observations on the instinctive activities of some of the monkeys used for operative purposes in connection with the studies of cerebral function have been made by Dr. K. S. Lashley and the results have been published. This work referred especially to the use of the right

[1] C. C. Bidwell, Physical Review (2), VIII, p. 12 (1916).
[2] R. W. King; Physical Review (2), X, p. 291 (1917).

and left hands and to the modifiability of the use by practice. Another study of the same general character has been made by Dr. Clarke Kempf and the results are in process of publication.

The experiments of Dr. Mildred E. Scheetz, on the location of the stimulable areas of the monkey's brain, with special reference to the area lying within the central or Rolandic fissure, have been completed and await publication.

Other experimental work on the motor cortex has been continued, with special reference to the phenomena and the mode of recovery after the destruction of the motor area. The account of the results of this work will soon be published. Plans have been made to continue the investigation to include those subcortical parts which are supposed to assume the functions of the motor area when the latter is destroyed or otherwise made incapable of function.

ZOOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3–15.)

In the year just ended the experiments with small mammals, outlined in previous reports, have been continued successfully. A large portion of my time has been given to the immediate supervision of experiments in progress and the preparation of material for publication has been somewhat delayed. Nevertheless five short papers have been published within the year—two by Mr. Dunn, three by myself—and each of us has a more extensive paper nearing completion. A book, *Genetics and Eugenics,* published in December by the Harvard University Press, contains, through the generous policy of the Carnegie Institution, much material drawn from earlier publications, but here presented in more popular form.

The experiments with guinea-pigs secured in Peru in 1911 are nearing completion and a final report upon them will, it is hoped, be submitted soon. A report on certain of the rabbit experiments has been in manuscript for several months and requires only the preparation in final form of certain charts to make it ready for publication.

For the coming year it is planned to discontinue work with guinea-pigs altogether, to limit the work with mice to a single problem, and to concentrate on the work with rats and rabbits, which is presenting new and interesting aspects.

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